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PHYTOPATHOLOGY

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PATHOGENICITY AND CULTURAL CHARACTERS OF THE APPLE SOOTY-BLOTCH FUNGUS[1]

R. C. BAINES AND M. W. GARDNER[2]

(Accepted for publication March 21, 1932)

Cultures of sooty blotch have been obtained from the fruit of apple and wild crab apple and from the young twigs of 23 other species of trees, shrubs, and vines. In culture the fungus grows slowly and produces a tough, leathery, black, heaped-up thallus from which gelatinous spore masses ooze out in great abundance. With spores from pure cultures from apple and 14 other hosts, successful inoculation of apples was obtained. The incubation period in a cool moist chamber is 2 to 3 weeks and in the orchard, 1 to 2 months. On 12 of the wild hosts sporulating pycnidia were found in late May and early June. The spores usually are bicellular.

ISOLATION OF SOOTY-BLOTCH FUNGUS FROM VARIOUS HOSTS

According to Duggar (2, p. 367) Floyd found sooty blotch on 25 species of nonpomaceous trees and shrubs in the vicinity of Columbia, Missouri. Colby (1) observed sooty blotch on apple twigs and fruit, peach twigs, blackberry canes, and on the stems of black mustard. Doyle Zaring,[3] working in this laboratory, obtained the sooty-blotch fungus from apple in pure culture in 1928 by means of tissue plantings in agar plates.

Pure cultures of what appear to be the same fungus have been obtained from sooty blotch (3) on the fruit of apple, *Pyrus malus,* and wild crab apple, *Pyrus coronaria,* and on the young twigs of the following 23 different hosts collected on various dates in the vicinity of La Fayette: hawthorn, *Crataegus mollis;* wild blackberry, *Rubus allegheniensis;* papaw, *Asimina triloba;* spice bush, *Benzoin aestivale;* sassafras, *Sassafras variifolium;* leatherwood, *Dirca palustris;* red elm, *Ulmus fulva;* white ash,

[1] Contribution from the Botany Department, Purdue University Agricultural Experiment Station, La Fayette, Ind. Portions of a thesis submitted by Mr. Baines to the Graduate School of Purdue University in partial fulfillment of the requirements for the M.S. degree are incorporated.

[2] The writers wish to acknowledge the cooperation of Prof. C. L. Burkholder and the Department of Horticulture, the assistance rendered by Prof. E. J. Kohl, R. W. Samson, and L. B. Lockwood, and helpful advice received from Dr. C. L. Shear.

[3] M.S. thesis, Purdue University, 1929. Unpublished.

Fraxinus americana; wild grape, *Vitis cordifolia;* hard maple, *Acer saccharum;* bladder nut, *Staphylea trifolia;* smilax, *Smilax hispida;* sycamore, *Platanus occidentalis;* willow, *Salix nigra;* prickly ash, *Zanthoxylum americanum;* dogwood, *Cornus rugosa,* and *Cornus alternifolia;* tulip tree, *Liriodendron tulipifera;* wahoo, *Evonymus obovatus;* bittersweet, *Celastris scandens;* red bud, *Cercis canadensis;* Kentucky coffee tree, *Gymnocladus dioica;* and white oak, *Quercus alba.*

From all of these hosts, except red elm, the fungus was isolated from tissue plantings. Small pieces of the host tissue bearing the fungus were first placed in 95 per cent alcohol to remove any air bubbles from the surface, then sterilized in mercuric chloride for 5 to 10 seconds, rinsed in water, and planted on poured plates of potato-dextrose agar. Since sooty blotch is superficial, the success of the method consists in sterilizing long enough to kill all of the contaminating organisms present, and presumably not long enough to kill all of the hyphae of the sooty blotch. The mycelium at the base of the aggregate masses of the sooty-blotch thallus probably escapes the sterilization by being in very close contact with the cuticle and protected from the disinfectant by the mycelium covering it.

The sooty-blotch fungus first became visible as a dark, compact mass of hyphae about the edge or on the surface of the tissue fragment in about 5 to 8 days at 25° C. The fungus grows slowly but extrudes gelatinous masses of spores promptly and in abundance. Because of other fungi growing from the tissue fragments, the fungus was not easily isolated by this method and was more easily isolated from apple than from the other hosts. In one instance, for example, it was isolated from 18 per cent of the 174 tissue plantings from apple fruits. The method described by Simmonds (7), in which the fragments of host tissue are not surface sterilized but are thoroughly washed in sterile distilled water, did not give satisfactory results. Groves (4), however, has made successful use of a modification of this method.

Very satisfactory results in isolating the fungus were obtained in the spring of 1931 by the dilution plate method, the inoculum being a suspension of the spores produced in the pycnidia on the twigs of the various hosts. By this method pure cultures were readily obtained from blackberry, bladder nut, hawthorn, leatherwood, smilax, willow, prickly ash, papaw, red elm, sassafras, and hard maple and were identical with the cultures previously isolated.

PYCNIDIA AND SPORE PRODUCTION ON THE VARIOUS HOSTS

Observations made in 1930 and 1931 showed that immature pycnidia were present on the twigs of the various hosts in the fall and that in the spring immature spores were present in these pycnidia. The course of de-

velopment of the pycnidia and spores in the spring of 1931 was followed by a microscopic examination of specimens collected at 2-week intervals from blackberry, white ash, white oak, papaw, smilax, bladder nut, red elm, hard maple, sassafras, and leatherwood. From March to June the pycnidia were found in progressive stages of maturity, and on May 30 mature spores were found in abundance. On June 6, after a heavy rain on the preceding day, it was found that nearly all of the pycnidia were empty. This would indicate that liberation and dissemination of the spores occurred during the rain on June 5.

Between March 31 and April 19, 1931, twigs of blackberry, white ash, papaw, smilax, bladder nut, red elm, hard maple, sassafras, leatherwood, willow, bittersweet, hawthorn, and prickly ash, bearing sooty blotch, were brought into the laboratory and placed in moist chambers at room temperature. The moist chambers were 2-quart Mason jars, containing about an inch of water and closed with loose cotton plugs. Under these conditions the maturity of the pycnidia was hastened and mature spores were obtained after an incubation period of 8 to 24 days, some as early as April 12.

From the spores produced in the pycnidia on these specimens incubated in the moist chambers plates were poured and pure cultures of the fungus obtained from all of the host species except white ash, sassafras, hard maple, and bittersweet. Pure cultures also were obtained from spores in the pycnidia on sassafras and hard maple collected on June 3. As has been previously mentioned, these cultures proved identical with those isolated from the tissue plantings.

Observations made in the early spring of 1932 indicate that sooty-blotch pycnidia were much more abundant on the various hosts than in the preceding season. This is not surprising because pycnidia are produced on mycelium that developed during the preceding year, and, as will be shown later, 1931 was more favorable for sooty blotch than 1930.

PATHOGENICITY OF THE CULTURES ON GREEN APPLES IN A MOIST CHAMBER

Before the cultural characteristics of the fungus were studied in detail, the pathogenicity of the cultures on apple fruits was first tested. In order to make inoculations on apples under controlled conditions and to maintain the fruits in sound condition for a period long enough for the fungus to develop, use was made of a large cool moist chamber in the greenhouse. This was a frame structure covered with burlap and kept wet with running water from a reservoir on top of the chamber. Evaporation from the wet burlap kept the temperature down to 18 to 22° C. in the chamber.

The fruits were washed and placed on galvanized-iron wire screen stretched over porcelain cake pans full of water, so that the pedicels of the

apples extended down through the screen into the water. These pans were placed on shelves in the moist chamber. By this method freshly picked green apples were successfully kept over 2 months.

The apples were inoculated by atomizing them with a spore suspension from the cultures and subsequently were atomized with distilled water twice daily. With pathogenic cultures abundant infection of a severe type was apparent on the apples in 2 to 3 weeks. The noninoculated apples used as controls remained free from infection, as well as those inoculated with spores from nonpathogenic cultures. No differences in the type of infection with the various cultures were observed. The results of the in-

TABLE 1.—*Inoculation of apples in a moist chamber with spores from sooty-blotch cultures from various hosts, 1930 and 1931*[a]

Source of culture	Variety of apple	Number inoculated	Percentage infected	Number of reisolations
Apple	Walbridge	69	100	29
"	Grimes	30	100	.....
"[b]	Ben Davis	20	100	.....
White ash	Walbridge	42	100	17
" "	Grimes	30	100	.....
" "	Ben Davis	10	100	.....
Papaw[b]	Walbridge	47	100	6
"	Grimes	29	100	3
"	Ben Davis	10	100	.....
Hawthorn[c]	Walbridge	24	100	8
"	Ben Davis	20	100	.....
Sycamore	Grimes	12	100	14
"	Ben Davis	10	100	.....
Grape	Walbridge	12	100	.....
"	Ben Davis	10	100	.....
Prickly ash	Grimes	12	100	13
Spice bush	Walbridge	12	100	16
Bladder nut	Ben Davis	10	100	1
Leatherwood[b]	" "	20	100	1
Red elm	" "	10	100	2
Smilax[b]	" "	20	100	1
Willow[b]	" "	20	100	.....
Maple[b]	" "	20	100	4
Sassafras	" "	10	100	1
Controls	Walbridge	62	0	.....
"	Grimes	24	0	.....
"	Ben Davis	20	0	.....

[a] Inoculated between June 26 and October 18.

[b] Two cultures used.

[c] Three cultures used.

oculation of Walbridge, Grimes and Ben Davis varieties of apples in the greenhouse in 1930 and 1931 are summarized in table 1.

Sooty blotch was produced on apples in the greenhouse moist chamber by inoculations with spores from cultures from sooty blotch on apple (2 cultures), papaw, prickly ash, hawthorn (3 cultures), white ash, sycamore, spice bush, grape, smilax (2 cultures), willow (2 cultures), sassafras, red elm, hard maple (2 cultures), leatherwood (2 cultures), and bladder nut. No sooty blotch was produced by inoculating apples with spores from 2 cultures from blackberry.

In the successful inoculation of apples with spores from cultures, numerous dense black colonies were usually obtained. The blotch, representing the thallus of the fungus, apparently did not increase in size after becoming dark and visible but did increase in thickness. In 1930 infection was obtained throughout the summer and as late as October 18. Apples inoculated in early October developed a lighter type of infection than that produced on apples inoculated during June, July, and August.

The fungus was reisolated from the infected apples in many of the tests and proved to be identical with the original culture from which the inoculum was taken.

INOCULATIONS IN THE ORCHARD

Sooty blotch was produced on inoculated apples in the orchard during the season of 1930, when no natural infection was observed either on the 1,375 uninoculated apples used as controls or on apples in neighboring orchards and the commercial crop. The apples were inoculated during a rain or the period of high humidity immediately following a rain by atomizing with a spore suspension taken from the cultures. In all of the inoculations except those on 1 tree, the inoculated apples were not bagged or protected in any way. No spray was applied to the apples after the calyx application, except that certain trees, as indicated in table 2, were sprayed with lime sulphur 1 to 50 on July 10.

In 1930 sooty blotch was produced on 6 varieties of apples in the orchard (Table 2) by inoculating with spores from cultures from sooty blotch on apple, papaw, and white ash on June 6, 7, 11, 16, 17, and 30. No infection was obtained by inoculations with spores from a culture from hawthorn, although this was pathogenic in the moist chamber. The severity of the infection varied from a single small thallus to numerous colonies coalescing to form large, black, dense, irregular blotches partially covering the apple, and no differences in the pathogenicity of the cultures from apple, white ash, and papaw were noted. Reisolations of the pathogenic cultures were made. No infection was secured on the early varieties Yellow Transparent, King David, Maiden Blush, and Wealthy, all of which were harvested on

or before August 26. Inoculations made on Grimes, August 5, had not developed infection on September 19, the date of harvesting. It may be that infection took place on these early varieties but did not have sufficient time to become visible under the existing conditions.

Only about 5 per cent of infection was obtained from inoculations made on June 11 on apples later sprayed with lime sulphur 1–50 on July 10,

TABLE 2.—*Results of inoculation of apples in the orchard, with spores from cultures of sooty blotch, 1930 and 1931*

Date inoculated	Source of culture	Tree No.	Variety inoculated	Number fruits inoculated	Date infection noted	Percentage infected
6–6	Apple	1	Rome	140	9–1	26[a]
6–6	"	2	Jonathan	128	8–26	64[a]
6–6	White ash	2	"	121	8–20	35
6–6	Papaw	2	"	290	8–26	60
6–6	Hawthorn	2	"	120		0
6–7	Apple	3	Seedling	150	8–26	50[a, b]
6–7	"	4	King David[c]	193		0
6–11	"	5	Jonathan	48	9–1	38
6–11	"	6	Grimes	76	9–1	60[a]
6–11	"	7	Delicious[d]	269	9–11	5[b]
6–11	"	8	Bismarck[d]	190	9–11	5[b]
6–11	"	9	Bertha	89	8–21	34.8
6–11	Bladder nut	9	"	100	8–21	2
6–12	Apple	10	Delicious	10	8–21	100[a]
6–12	Willow	10	"	55	8–21	78[a]
6–12	Sycamore	11	Bismarck	135	8–21	24[a]
6–12	Apple	12	Senator	15	8–21	40
6–12	Leatherwood	12	"	95	8–21	44[a]
6–12	Grape	12	"	60		0
6–12	Apple	13	Satsuma	30	8–21	53
6–12	Red elm	13	"	125	8–21	1
6–12	Hawthorn	14	Greenville	60		0
6–12	Blackberry	14	"	75		0
6–12	Apple	15	Salome	98	8–21	55
6–12	Smilax	15	"	185	8–25	18[a]
6–12	Maple	15	"	105	8–21	19
6–12	Apple	16	Rome	103	8–21	58
6–12	White ash	16	"	98	8–21	70
6–16	" "	17	Satsuma[d]	80	9–19	5[b]
6–17	Apple	17	" [d]	243	9–11	10[b]
6–17	Papaw	17	" [d]	60	9–11	5[b]
6–30	Apple	18	Rome[d]	300	9–11	5[b]
7–13	"	19	"	133	8–21	52
7–13	White ash	19	"	75	8–21	53
7–19	" "	20	"	257	8–21	80
7–19	Apple	20	"	125	8–21	90
8–3	"	21	Black Twig	240	9–2	85
8–3	White ash	21	" "	264	9–2	92
8–5	Apple	22	Grimes	250		0

[a] Sooty-blotch fungus reisolated.
[b] Estimate. Fruit picked before counts were made.
[c] Fruit picked August 26, 1930.
[d] Fruit sprayed July 10 with lime sulphur 1–50.

while on apples not receiving the spray 38 to 60 per cent of infection was obtained. This decrease in the percentage of infection on the sprayed fruit was probably the result of the fungicidal action of the spray applied on July 10.

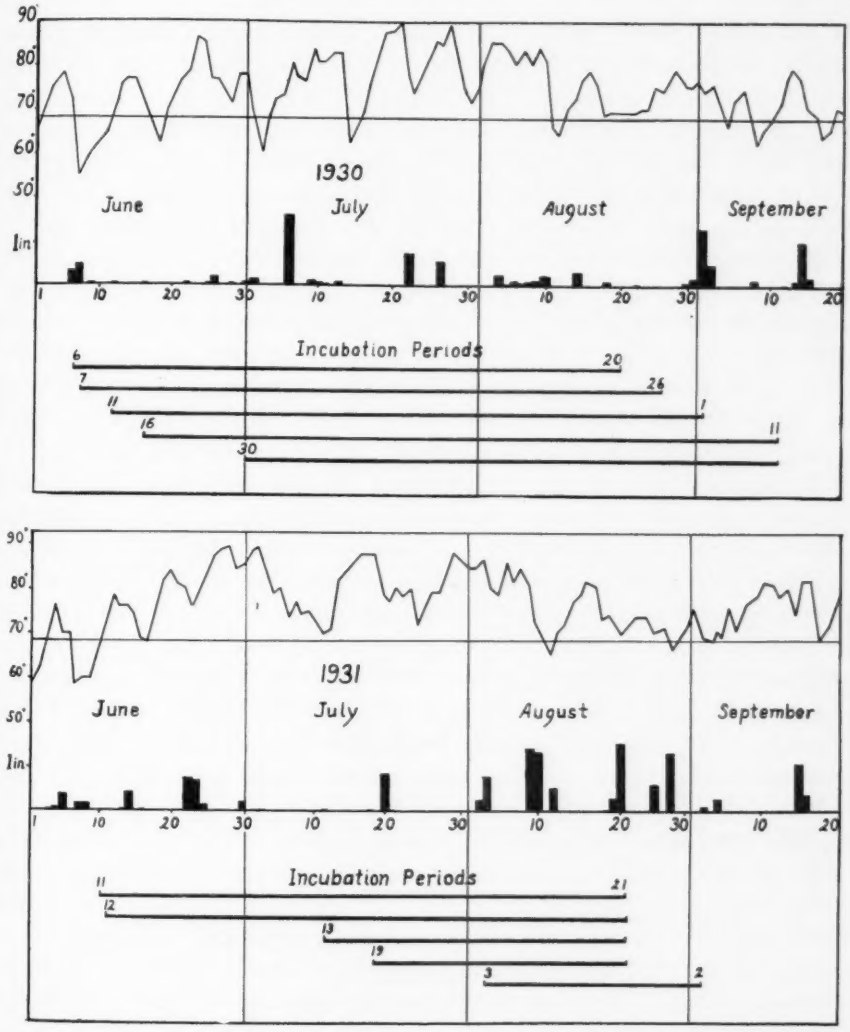

FIG. 1. Incubation periods of sooty blotch in orchard inoculation tests and the weather conditions in 1930 and 1931. The horizontal lines represent the incubation period between date of inoculation and date when sooty blotch became visible. The curve represents the average daily temperature and the vertical columns the rainfall in inches (from Climatological Data). The optimum temperature for the fungus, 68° F., is indicated.

The infection on apples inoculated on June 6, 7, 11, 16, and 30, 1930, did not become visible until after August 20 and the incubation periods were 75, 80, 82, 87, and 73 days, respectively (Fig. 1). The long duration of the incubation period may have been the result of the very hot and dry summer.

During the period of inoculation in June, 1930, conditions were favorable for infection, but the climatic conditions during July, except for a cool period of 3 days, were not favorable for the development of the fungus, which grows very slowly at a temperature above 80° F. and a humidity less than 90 per cent, as will be shown later. In August, 1930, rainfall occurred during a period from the 4th, to the 10th, again on the 14th and on the 18th, and the high temperature (90–100° F.) of the 1st 9 days was followed by lower temperatures (80–90° F.) during the remainder of the month and throughout September. The lower temperature and high humidity of mid-August favored the development of the fungus, which first became evident on the apples as small dark sooty blotches on August 20. As in the moist-chamber inoculations, it was noticed that there was little or no increase in the size of the colonies after they turned dark and became visible; consequently, their early stages of development were not observed.

Inoculations were made in the orchard again in 1931 with a number of cultures not previously used. In all but 2 of the tests parallel inoculations were made with a culture of proved pathogenicity from apple. In 1931 sooty-blotch infection was observed on apples in neighboring orchards and also on the commercial crop. In the inoculation tests, however, the 600 noninoculated apples used as controls remained free from infection. In 1931 sooty blotch was produced on 8 varieties of apples in the orchard (Table 2) by inoculations on June 11, 12, July 13, 19, and August 3 with spores from cultures of sooty blotch from apple, bladder nut, papaw, willow, sycamore, leatherwood, red elm, smilax, hard maple, and white ash. Reisolations were made from the apples inoculated with the cultures from apple, willow, sycamore, leatherwood, and smilax.

As compared with the culture from apple, some of the cultures showed much lower percentages of infection. For example, no infection was obtained with the cultures from grape and hawthorn, and the cultures from red elm, smilax, hard maple, and sycamore produced low percentages of infection, although all of these cultures had produced abundant infection in the moist chamber. The culture from blackberry was nonpathogenic in the moist chamber as well as in the orchard.

The first evidence of infection in 1931 on apples inoculated on June 11, 12, and July 13 and 19 was noted on August 21 (Fig. 1), while apples inoculated on August 3 developed the first evidence of infection on Septem-

ber 2, 30 days after inoculation. Thus, the period between the date of inoculation and of evident infection decreased from 71 days early in the season to 30 days late in the season.

THE RELATION OF CLIMATIC CONDITIONS TO INCUBATION PERIOD

The relation of climatic conditions to the incubation period for the orchard inoculations made at different dates is shown in figure 1. In 1930 the incubation periods were all long, owing probably to the high temperatures and light rainfall of June and August, and the inoculations made on June 16 showed up no sooner than those made on June 30. In 1931 there was more rain in June and August, though less in July, and infection from inoculations made on June 11 and 12 showed up no sooner than from those made a month later. Apparently, the high rainfall and lower temperatures of August favored the development of the sooty-bloth colonies. The progressive shortening of the incubation period with each later inoculation in 1931 suggests that cool moist conditions late in the summer favor the development of the colonies. Because the fungus grows best at a fairly low temperature (68° F.) and almost none at all at 86° F., (midsummer is usually too hot in this region for its best growth) it is suggested that most of the growth is made in June and August. Since high humidity also is necessary for the growth of the fungus, as will be shown later, it is probable that rainfall is more important during these months than in July. This might account for the much heavier natural infection in 1931 than in 1930. The heavy dews that occur in August no doubt also favor the development of the fungus.

Since the spores are mature in late May and early June it seems likely that in nature the fungus becomes established on the fruit early in the season. Apparently, however, its development may be very slow or completely suspended during hot, dry weather, although the small colonies may be present in a colorless invisible condition. With the advent of lower temperature and higher humidity in August, the colonies probably enlarge and become pigmented and visible.

THE SOOTY-BLOTCH FUNGUS IN CULTURE

On potato-dextrose agar the colonies of the fungus isolated from apple are slow growing and form a dark, dense, compact, leathery thallus, which piles up and extrudes masses of spores promptly and in abundance (Fig. 2, E). The older mycelium bears numerous short lateral hyphae branching mainly at right angles to the main hyphae. The spores are produced in cavities at various levels in the thallus, break through the dense layer of mycelium, and ooze out on the upper surface of the thallus and around its

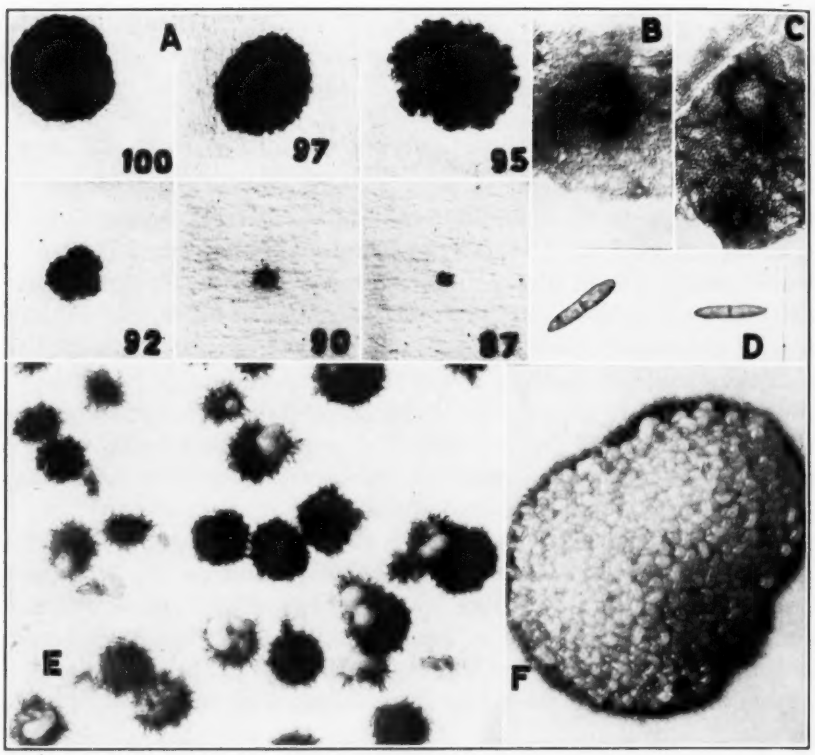

FIG. 2. A. Growth of sooty-blotch colonies on filter-paper pads with potato-dextrose nutrient solution after 2 months under humidities of 87 to 100 per cent. The fungus grew well at humidities above 92 per cent. B and C. Sooty-blotch pycnidia on blackberry: B shows radial cracks in the ruptured top; C shows the sides forced wide apart and the spore mass within. X 170. D. Spores from a culture of sooty blotch from apple. X 375. E and F. Sooty-blotch fungus on potato-dextrose agar. E. 14-day-old sporulating colonies on a poured plate inoculated with spores from a culture of sooty blotch from apple. The fungus produces a dense black thallus on the surface of which the spores ooze out in gelatinous masses. X 3. F. 18-day-old colony of sooty blotch from willow with the surface nearly covered with the spore masses. X 3.

margin in gelatinous masses that may entirely cover it (Fig. 3, B). When first extruded the spore masses are whitish or pinkish, but later turn dark. When the thallus has dried somewhat and drawn up to form a hollow mound above the agar, the spores may be extruded onto the agar underneath it.

The spores germinate readily by elongating at both ends, and it is rather difficult to find very many ungerminated spores in the spore masses produced in culture. In spore smears on moist fresh agar, the spores bud and proliferate directly, producing a pinkish yeast-like type of growth. In the

later stages of development or when the substratum dries, the characteristic dark colony may be produced. Isolated spores on poured plates of agar, however, characteristically produce the black mycelial colonies.

Cultures from the other hosts on potato-dextrose agar are, in general, similar in type of growth and sporulation to those from apple, but some differences have been observed. Groves (4) has reported differences in cultural characters among the various sooty-blotch isolations. In order to determine whether there were differences between the cultures from different hosts, the cultures from 17 hosts were compared on 13 different agar media in Petri dishes at 24° C. With all of these cultures, except those from blackberry and dogwood, infection had been obtained on apples.

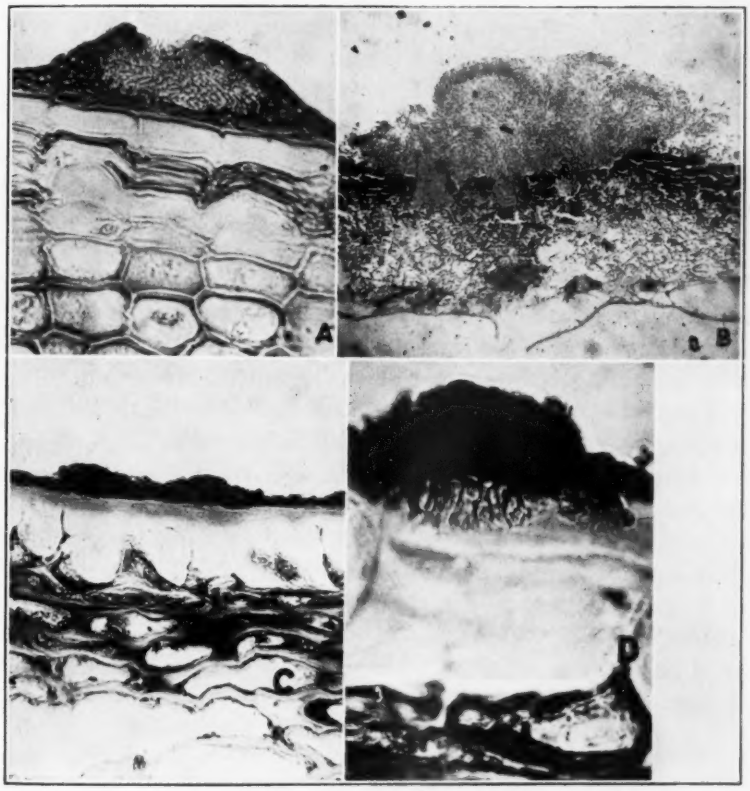

FIG. 3. Cross-sections of sooty blotch. A. Pycnidium on leatherwood. X 530. B. Young sporulating colony on potato-dextrose agar. Spores are produced in cavities at various levels in the thallus and break through to the surface in gelatinous masses. X 14. C and D. On Grimes apple. C. Dense layer of mycelium on surface of cuticle. X 345. D. Short hyphae, usually in clusters, penetrating only a fraction of depth of cuticle. X 960.

On all of the media the cultures from apple, papaw, hawthorn, leatherwood, bladder nut, hard maple, white ash, smilax, sassafras, sycamore, spice bush, prickly ash, and dogwood were more or less alike and produced dark, heaped-up colonies on potato-dextrose agar with little or no aerial mycelium and spore masses varying from sparse to abundant. On oatmeal agar the colonies were prostrate and did not sporulate. The cultures from willow (Fig. 2, F), red elm, and blackberry differed in that the colonies on potato-dextrose agar were prostrate and sporulated more abundantly. The colonies from the blackberry culture had a whitish margin. The culture from grape was of lighter color, produced more aerial mycelium, grew more rapidly than the others, and sporulated on oatmeal agar.

In order to determine the suitability of various sources of carbon for the fungus, a culture of proved pathogenicity from apple was grown on agar media containing as a carbon source, dextrose, levulose, sucrose, maltose, lactose, malt extract, dextrin, or potato starch in concentrations of 2, 1, 0.5, 0.1, and 0.05 per cent. Potato extract in concentrations of 20, 10, 5, 1, and 0.5 per cent also was used as a carbon source. At the higher concentrations of all the carbon sources the sooty-blotch fungus made a good growth, somewhat better on levulose, sucrose, dextrin, potato starch, and potato extract than on the other carbon sources. Spores were produced on the malt-extract agar in all concentrations and in the 3 higher concentrations of potato extract, but not on the other media.

The rate of growth of the fungus on 5 kinds of nutrient agar was determined by measuring the diameter of the colonies after 7 and 15 days at 24° C. The growth was most rapid on prune agar, the colonies measuring 7.1 mm. in diameter at 7 days and 11.6 mm. at 15 days. On potato agar with 2 per cent dextrose, the diameter was 5.1 mm. at 7 days and 8.6 mm. at 15 days, and on Leonian's synthetic agar (5, p. 762) the measurements were 4.6 mm. and 7.0 mm., respectively. On these 3 media the colonies were heaped-up and produced spores. The poorest growth occurred on corn meal and oatmeal agar, the colonies were prostrate, and no spores were produced. On corn-meal agar the diameter at 7 days was 4.2 mm. and at 15 days, 8.0 mm. On oatmeal the corresponding dimensions were 4.3 mm. and 7.7 mm.

EFFECT OF TEMPERATURE, HUMIDITY, AND H-ION CONCENTRATION ON GROWTH OF THE FUNGUS

The temperature range for the growth of a culture from apple of proved pathogenicity was determined by measuring the increase in diameter of the colonies in Petri dishes on potato-dextrose agar at temperatures between 0 and 30° C., maintained within a degree. The average increase in diam-

eter of the colonies after 7 days was 0.4 mm. at 0°, 1 mm. at 6°, 2.8 mm. at 10°, 2.6 mm. at 13°, 3 mm. at 15°, 3.4 mm. at 18°, 6.9 mm. at 20°, 5.3 mm. at 27°, 0.4 mm. at 30°, and after 14 days was 1.1 mm. at 0°, 1.9 mm. at 6°, 4 mm. at 13°, 7 mm. at 18°, 10.6 mm. at 20°, 9.4 mm. at 24°, 8.6 mm. at 27°, and 1 mm. at 30°. Therefore, growth was most rapid at 20° and was good between 18 and 27° C. Almost no growth occurred at 0 or 30° C. The virtual failure of the fungus to grow at 30° C. (86° F.) may explain its slow development in hot weather, and the low optimum of 20° C. (68° F.) explains why it is favored by cool weather.

For use in testing the effect of humidity on the growth of the fungus, filter-paper pads were saturated with a 2 per cent potato-dextrose nutrient solution, placed in small preparation dishes, and sterilized. These preparation dishes were then placed inside of larger ones, containing different concentrations of salt solution to control the humidity. The filter-paper pads were allowed to remain over the different salt solutions for 4 days, so that equilibrium in vapor pressure was presumably established between the paper and the salt solution. According to Lesage (6), the humidity over a salt solution varies inversely with the concentration of the salt solution. According to his formula, the following humidities were provided: 97 per cent (over 5 per cent NaCl), 95 per cent (8.3 per cent NaCl), 90 per cent (16.6 per cent NaCl), 87 per cent (21.6 per cent NaCl), and 85 per cent (25 per cent NaCl).

The fungus was planted in the center of each filter-paper pad by touching with a platinum needle covered with spores from the gelatinous spore mass of a culture. Five colonies were grown in each humidity. The average increase in diameter of the colonies after 2 months was 15.5 mm. at a calculated humidity of 100 per cent, 11.1 mm. at 97 per cent, 12 mm. at 95 per cent, 5.7 mm. at 92 per cent, and 1.6 mm. at 90 per cent, and no growth occurred at humidities of 87 and 85 per cent. Therefore, the growth was best in the higher humidities (95 per cent and above) and rapidly became less with decrease in humidity (Fig. 2, A).

This test was repeated in a manner similar to that described above, except that the filter-paper pads were not placed over the salt solutions until 4 days after inoculation. At this time small black colonies were visible. The relation of humidity to growth was found to be about the same as in the previous test.

Since this fungus is superficial on its host, it seems safe to assume that atmospheric humidity will directly affect its growth and, consequently, that growth will occur only during periods of very high humidity.

On potato-dextrose agar adjusted to different hydrogen-ion concentrations, the average diameter of the colonies after 10 days at 24° C. was 4.1

mm. at pH 3.3, 4.5 mm. at pH 3.6, 7.3 mm. at pH 4.15, 6.5 mm. at pH 4.66, 7.4 mm. at pH 5.6, 7.5 mm. at pH 6.26, 8.4 mm. at pH 6.75, 8.6 mm. at pH 7.37, 6 mm. at pH 7.8, and 4.7 mm. at pH 8.3. Between pH 4.15 and 7.8 the fungus grew well, and its limits of tolerance were not reached in these tests. Apparently, it tolerates a very wide range of H-ion concentration.

MORPHOLOGY OF THE FUNGUS

In sections of apple-fruit tissue of the Grimes variety embedded in nitrocellulose and stained with safranin, the fungus was observed to be superficial (Fig. 3, C), as Colby (1) reported, but with occasional clusters of short hyaline hyphae extending slightly into the cuticle (Fig. 3, D). These clusters of short hyphae were usually under the immature pycnidia and penetrated only a fraction of the depth of the waxy cuticular layer. Groves (4), however, has found types of sooty blotch that penetrate beneath the cuticle.

The morphology of the fungus has been described by Colby (1). Mature pycnidia, as found on twigs in May and June, 1931, were dark brown to black, dimidiate, scattered and superficial. The pycnidia varied in size, those on leatherwood (Fig. 3, A) were 60 to 130 μ in diameter, 20 to 40 μ in height, with a cavity 30 to 87 μ in diameter. On apple fruit, where only immature pycnidia have been found, they were 85 to 140 μ in diameter. On blackberry the pycnidia were 60 to 130 μ in diameter, on bladder nut, 61 to 105 μ, and on hard maple 85 to 130 μ. The top of the pycnidium is ruptured irregularly near the center by the formation of radial cracks (Fig. 2, B and C) and is forced wide open, apparently, by the pressure of the mass of spores within. The flaps formed by the radial cracks fall back over the empty cavity after the spores are discharged, leaving a stellate opening.

The immature spores are unicellular, but the mature ones, found in abundance in late May and early June, 1931, were bicellular, sometimes tricellular, hyaline, slightly pointed at the ends and measured 2 μ x 10–12 μ. These spore measurements agree well with Floyd's (2), but Colby (1) found the spores to be larger, and both found them to be unicellular.

In culture the spores are produced in numerous cavities apparently without distinct walls, varying in size, and located at different depths in the thallus (Fig. 3, B). The spore masses ooze out in abundance on top of the thallus and around its margin (Fig. 2, E). The spores produced in culture (Fig. 2, D) are slightly larger than those produced on the host, measuring 2–3 μ x 12–14 μ; but, as previously mentioned, they start to grow so promptly in their gelatinous matrix by elongating at the ends and producing additional septa that ungerminated spores are not easily found in the cultures, and measurements of such spores are not reliable.

While we have not observed sporulating pycnidia on apple the fact that the spores from the pycnidia of sooty bloth on 10 other hosts were bicellular and that the spores produced in cultures from apple as well as the other hosts were, likewise, bicellular would indicate that the sooty-blotch fungus, *Gloeodes pomigena*, is characterized by bicellular rather than unicellular spores.

SUMMARY

The sooty-blotch fungus has been isolated in pure culture from apple and crab-apple fruit and from the young twigs of 23 other host species by means of tissue plantings or poured plates inoculated with spores from pycnidia on the hosts.

Pycnidia with mature spores were found in late May and early June on the twigs of 12 host species. The spores were liberated early in June. The mature spores are bicellular.

In a cool moist chamber, in the greenhouse, green apples were inoculated with spore suspensions and infection was obtained with the cultures from apple, papaw, white ash, sycamore, smilax, hard maple, willow, bladder nut, leatherwood, red elm, prickly ash, hawthorn, spice bush, grape, and sassafras. No infection was obtained with cultures from blackberry. The incubation period was 2 to 3 weeks.

In the orchard, sooty blotch has been produced on apples by inoculation with spores from cultures from the first 10 host species mentioned above. The incubation period varied from 1 to 2 months. The dry, hot weather of midsummer is unfavorable to the fungus.

Under the superficial thallus on the apple cuticle, clusters of short hyphae are found, penetrating a short distance into the cuticle.

The fungus grew well on a wide variety of agar media. Spore production in culture was favored by malt and potato extracts. Minor differences in cultural characters were noted. The fungus grows slowly and, on potato-dextrose agar, produces a more or less heaped-up, black, leathery colony and an abundance of spores that ooze out in gelatinous masses.

The optimum temperature for growth was about 20° C. Good growth occurred between 18 and 27° C. Practically no growth occurred at a humidity of 90 per cent or less. A wide range of H-ion concentration was tolerated.

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THE MECHANISM OF VARIATION IN IMPERFECT FUNGI: BOTRYTIS CINEREA

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INTRODUCTION

The subject of variation or subspecific grouping in fungi has been reviewed by Brierley in 2 recent papers (3, 4). Reference is made to these publications for a broad discussion of matters relating to the present topic.

The cosmopolitan gray-mold organism, *Botrytis cinerea* Pers. (*B. vulgaris* Fr.), furnishes an excellent example of a fungus species of a type that is of particular interest in the present connection. It is a common observation that much variation exists between different collections or isolations of fungi that pass for this species and that, in a general way, show a fair degree of uniformity. The uncertainty of specific limitations in such material seems to increase almost indefinitely with the multiplication of cultures, either from new material or from previous isolations.

Brierley's conception of the situation with this particular fungus is expressed as follows: "The species *Botrytis cinerea* may be visualized as, at any one moment, a cluster of numerous races or strains morphologically congruent on the host plant but *in vitro* showing marked and constant cultural differences." The same author points out the fact that since variants with morphologically or culturally distinct characters are so numerous there probably also exist physiologic strains that may or may not be morphologically alike. The manner of origin of the apparently numberless strains of this and other supposedly asexually reproducing fungi is a subject of much interest. The principal explanations that have previously been advanced for this condition are as follows:

Impure Material. This theory assumes that such fungi as *Botrytis cinerea* are composed of complex mixtures of established types and that repeated culturing from this complex by single-spore isolations or mass transfers results simply in separating from the mass either single strains or new combinations of strains *ad infinitum*. In case single-spore strains continue to vary, suspicion is directed at the technique of single-spore isolation. This explanation does not, of course, account for the original formation of these diverse strains.

Mutation. That variation goes on in many vegetatively propagating (asexual) fungi, even in strains originally established from unquestionable single-spore isolations, has been shown by many workers. The term "mutation" (saltation, dissociation, discontinuous variation) has been

rather loosely applied to characterize this phenomenon. (See discussion by Stakman *et al.*, 12, p. 53.) The extraordinary degree to which new variants appear in certain fungi has led others to seek some explanation of the remarkable behavior of these organisms more in keeping with the conventional principles of genetics (Brierley, 4). Meantime the need of far more cytological evidence and genetic analysis is evident and forms the motive of the work presented in this paper.

Hybridization. The existence of a more or less frequently occurring, though undiscovered, perfect or sexual stage of the fungus, making possible hybridization between species or strains, with heterozygosis and ordinary segregation in the offspring, has been suggested as an explanation of variation in fungi. Although no form of sexual fusion that could bring about hybridization, character combination, and segregation is ordinarily recognized in the so-called imperfect fungi *per se*, the fact should not be overlooked that *Botrytis cinerea* has, theoretically at least, a perfect, ascomycetous stage, represented by the species *Sclerotinia fuckeliana* de Bary. Although the apothecial form of the latter fungus is common in Europe on dead vine leaves, it has never, so far as we are aware, been reported in America, and considerable doubt prevails as to the relation between these 2 fungi. The original announcement in the matter by de Bary (1) certainly indicates uncertainty. Its confirmation by Pirotta (8) and Istvanffi (6), and the observations of Viala (14), Prillieux (9), Ferraris (5), and other European writers on vine diseases are hardly more convincing. Tubeuf (13) indicates doubt whether "*S. fuckeliana* and *B. cinerea* are stages in the life of the same fungus," although he has "observed the Peziza fruit, so easily cultivated from sclerotia gathered in the open air (*e.g.*, from vine leaves)." One of us (Smith, 10) concluded, on the basis of rather extensive work in America and Europe, that "so far as known no Peziza has ever been obtained from sclerotia developed from Botrytis." Brierley (3) states, "Many years' study of *B. cinerea* has given me no evidence of a connection with Sclerotinia."

H. H. Whetzel, in a personal letter, expresses the opinion from his own observations and studies that all Botrytis forms of the *cinerea* type are conidial stages of apothecial species belonging to the genus Sclerotinia, as that genus is now generally understood. He has established the connection between the apothecial form and the Botrytis stage of several species of Sclerotinia and has been able to confirm the connection between *S. fuckeliana* and the common Botrytis on grapes referred to by de Bary as *B. cinerea*. This statement is based upon his as yet unpublished researches. From all the evidence it appears to be true that there occurs commonly on vines, in southern Europe at least, an apothecial, Botrytis-associated Sclerotinia fungus that has not been found in America and apparently not in England.

Kharbush (7) reports the usual phenomena in the development of the ascogenous hyphae and asci in *Sclerotinia fuckeliana.*

Whether or not *Botrytis cinerea* develops an apothecial stage in California is, in fact, immaterial in the present connection if conidial reproduction be considered as representing purely asexual or vegetative multiplication of clones. Should crossing of strains and the development of a hybrid apothecial stage actually occur, resulting in heterozygosity, there would still be no provision for segregation or dissociation and for the origin of new strains in these conidial lines after their original development from ascospores. Whether, in fact, the formation of conidia from conidiophores or pycnidia in *fungi imperfecti* is as purely an asexual, vegetative reproductive process as the multiplication of higher plants by cuttings or stolons is a question that cannot be too positively answered in the affirmative until more cytological evidence is available.

Microconidia. The occurrence of specifically distinct bodies of this sort in *Botrytis cinerea* may have some possible significance, although there is little evidence that they have even enough power of germination to play any important rôle.

Anastomosis. Hyphal Fusions. Heterocaryosis. Mixochimaera. That anastomoses or fusions often take place between hyphae and germ tubes of many fungi,[1] affording a possibility for the interchange of cell contents, was figured and described by de Bary (1) and by many others since that time. The frequently occurring multinuclear condition in hyphal cells and spores of such fungi has suggested the possibility of an irregular distribution of genetically dissimilar nuclei in cell division or conidial formation. This phenomenon has been the basis of considerable speculation in relation to the origin of variation in fungi, although no actual, cytological evidence in the matter has been produced (see Brierley, 2, 3, 4).

CYTOLOGICAL STUDIES

Cytological studies carried on in connection with this work showed that the mycelial cells and conidia of Botrytis are multinucleate, containing comparatively large numbers of nuclei. Spores of the *a* homotype hereafter described contain from 6 to 18 nuclei and those of the *b* homotype from 3 to 9 nuclei, with much greater variation in the mycelial cells. Figure 1 shows the nuclei in hyphae and germinating conidia and also anastomosis between neighboring filaments. In D and E nuclei can be seen in the connecting strands and, in E, a hypha has arisen from this point. Anastomosis takes place by lateral fusions of hyphae near the growing tips or by the

[1] The term "heterocaryosis" precisely describes the condition of a cell containing 2 or more genetically different nuclei and, for this reason, its use seems preferable to "mixochimaera."

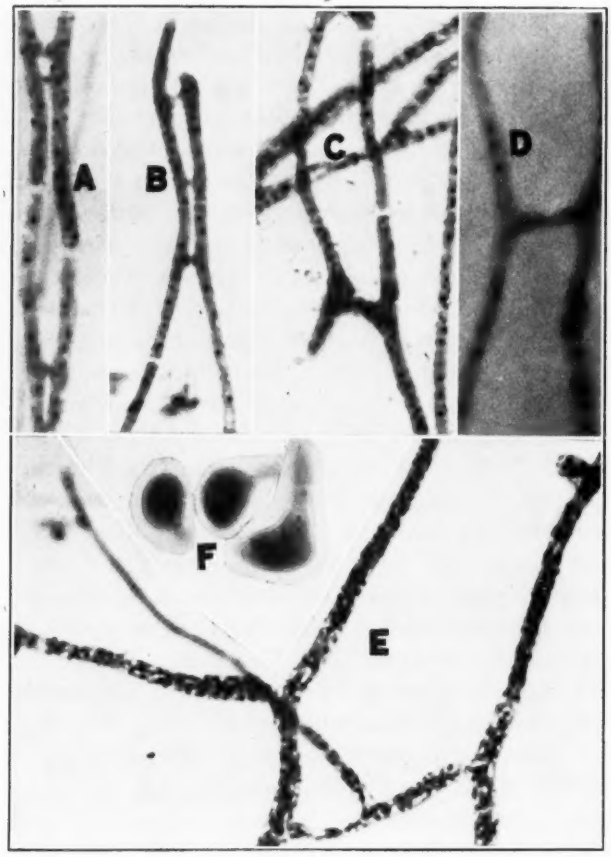

FIG. 1. A–E. Anastomosis in *Botrytis cinerea*. Note multinuclear condition of cells. F. Multinuclear germinating conidia.

pushing out from the sides of older filaments of new lateral hyphae, which fuse terminally with the tips of other similar hyphae or directly with the cells of neighboring hyphae. Fusion also may occur between the germ tubes of 2 conidia. Nuclear fusions were not observed.

ISOLATION OF TYPES OF BOTRYTIS

In connection with work on *Sclerotinia sclerotiorum* recently published by one of us (Smith, 11) 47 mass-transfer cultures of Botrytis were made from various samples of vegetation that had been obtained in different parts of California and incubated in moist chambers. The original cultures were mostly of the general type of *Botrytis cinerea*, although varying somewhat from each other, and, in some cases, mixed with other fungi. Reculturing

several times by mass transfer of small quantities of conidia to eliminate foreign fungi resulted finally in a series of apparently pure cultures of Botrytis showing considerable variation in type of mycelium, conidial production, presence, size and character of sclerotia, and other gross characters. Four monospore cultures were then made from each of the 47 strains. In some the 4 cultures looked identical, others showed decided variation. The series as a whole showed a wide range of variation. Many of the strains, in fact, might easily have been regarded as distinct species if the intermediate types had not been seen. This work clearly showed that (1) *B. cinerea* collected from different places in California has much variation and (2) single-spore isolations from apparently homogeneous mass-transfer colonies reveal further variation, so that the definition of specific limits is extremely difficult.

Further Analysis of Types of Botrytis cinerea by Single-spore Cultures. In order to study further the matter of variation in this fungus it was decided to make repeated monoconidial cultures of various strains for a number of generations, rather than follow the usual procedure of successive mass transfers of strains that had been subjected to single-spore culturing only in the original isolation.

METHODS

When single-spore cultures are to be made in large numbers (Fig. 2 represents 1,830 cultures) it becomes necessary to use an isolation method that is both precise and expeditious. Our technique was as follows: the approximate concentration of a spore suspension was determined by direct microscopic counts of spores carried in a 2-mm. loop. From this suspension 75 to 100 spores were transferred to a test tube containing 10 cc. of melted Czapek's medium made with 0.5 per cent agar. The low percentage of agar makes it possible to cover the bottom of 3 90-mm. plates with 10 cc. of medium, giving from 20 to 40 spores to each plate. The thinness of the film of agar greatly minimizes the possibility of spores being situated directly above one another. The spores were now allowed to germinate for from 12 to 16 hours, during which time they developed germ tubes from 5 to 10 times their own diameter. The Petri dish was then placed on the stage of a dissecting microscope with a magnification of about 35, the cover removed, and the spores picked up singly on the tip of steel needles and transferred to agar slants. The needles used were made from steel knitting needles ground down to a very fine point, the terminal millimeter tapering from 250 μ to 10 μ in diameter at the tip. Such a tip can readily be inserted under a germ tube and the entire spore lifted out. A needle of such fineness must be sterilized by chemical means, as it is immediately destroyed in a flame. All cultures were grown on potato-dextrose-agar

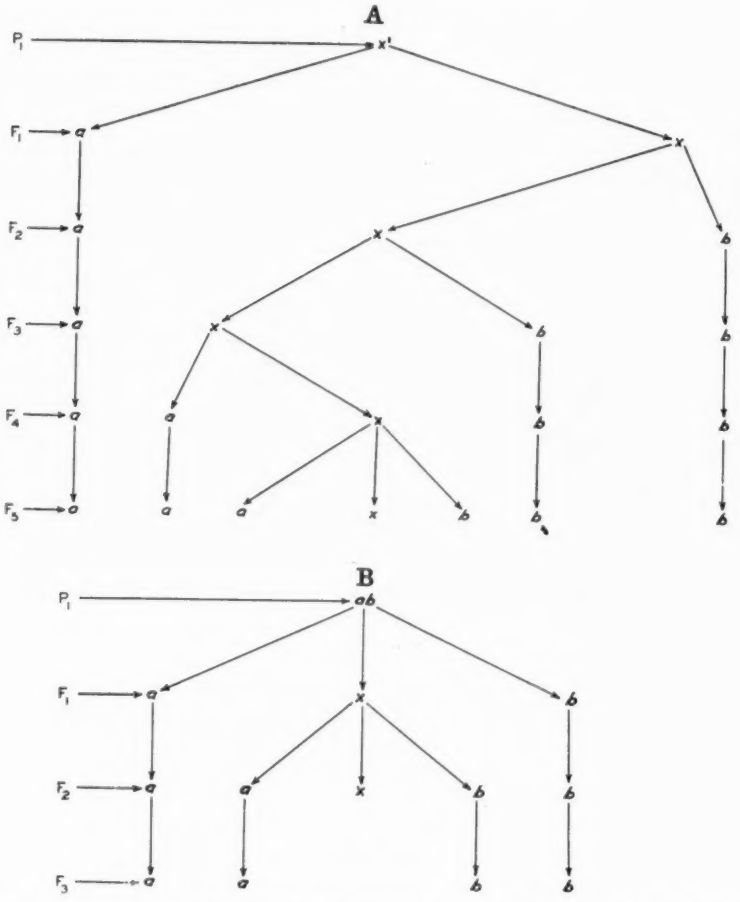

FIG. 2. A. The behavior of the progeny of a single conidium of *Botrytis cinerea* (strain x^1) through 5 generations, showing the separation of the homotypes *a* and *b* and the appearance of heterotypes *x*. The chart represents a total of 650 single-spore cultures. B. Behavior of the combination of strains *a* and *b* of *Botrytis cinerea* through 3 generations. The chart represents a total of 1,180 single-spore cultures.

slants in large test tubes 8×1 in., at room temperature for 10 days, at the end of which time records were taken and the next generation of single-spore cultures started.

From the 188 single-spore Botrytis cultures available, there were selected 8 of the *cinerea* type that represented the greatest morphological variation. From each of these, 25 single-spore cultures were made. Many of these showed almost absolute uniformity throughout the 25 tubes. Some showed quite striking variation. Figure 3, A and B, shows 2 tubes, each, of these 8 strains. From 1 tube of type 8 (Fig. 3, B, the 2 tubes at right

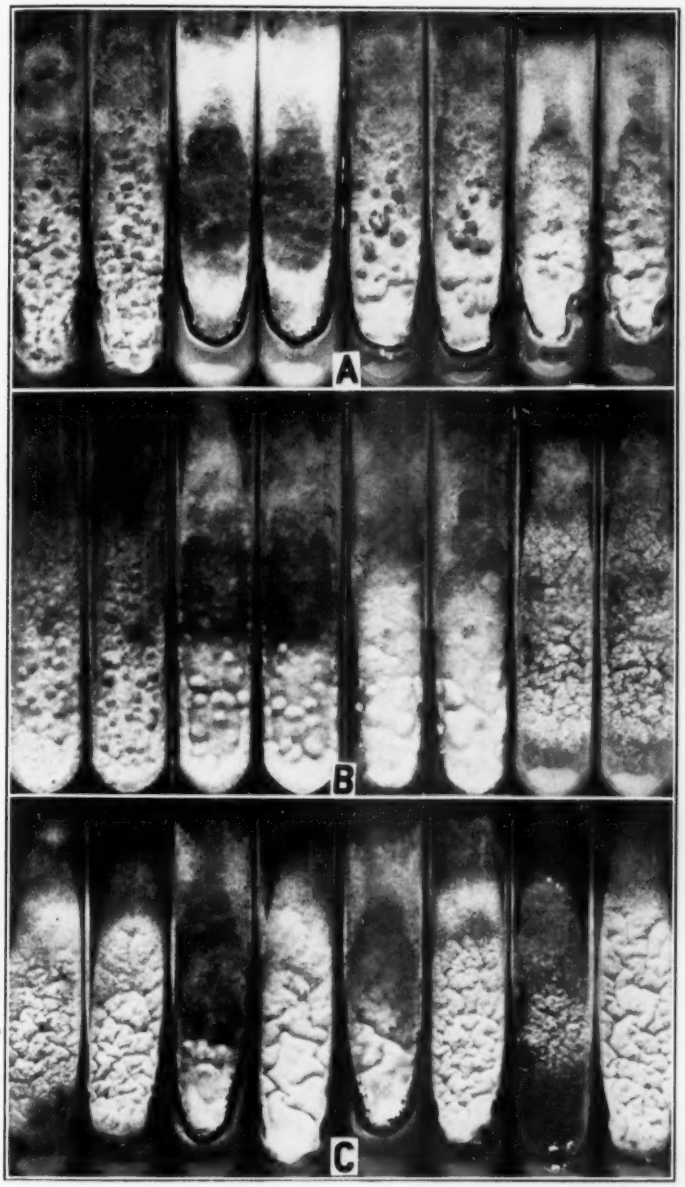

FIG. 3. A and B. Eight strains of Botrytis isolated by single-spore cultures from various collections; 2 cultures of each strain (1–8). C. Eight single-spore cultures from strain 8 in B, showing the variation that occurred after several generations of single-spore culturing.

end) (a strain in which variation occurred) 25 monospore cultures were made. Much variation appeared in these cultures, 8 of which are shown in figure 3, C.

From another of the original single-spore cultures from 1 of the 47 strains (marked x^1) 150 monospore cultures were grown. Of these, 143 looked alike and were labelled *a*, while the remaining 7, labelled *x*, differed materially from the *a* type in amount and color of mycelium, abundance of spore formation, and in other gross features (Figs. 2, A and 4). From

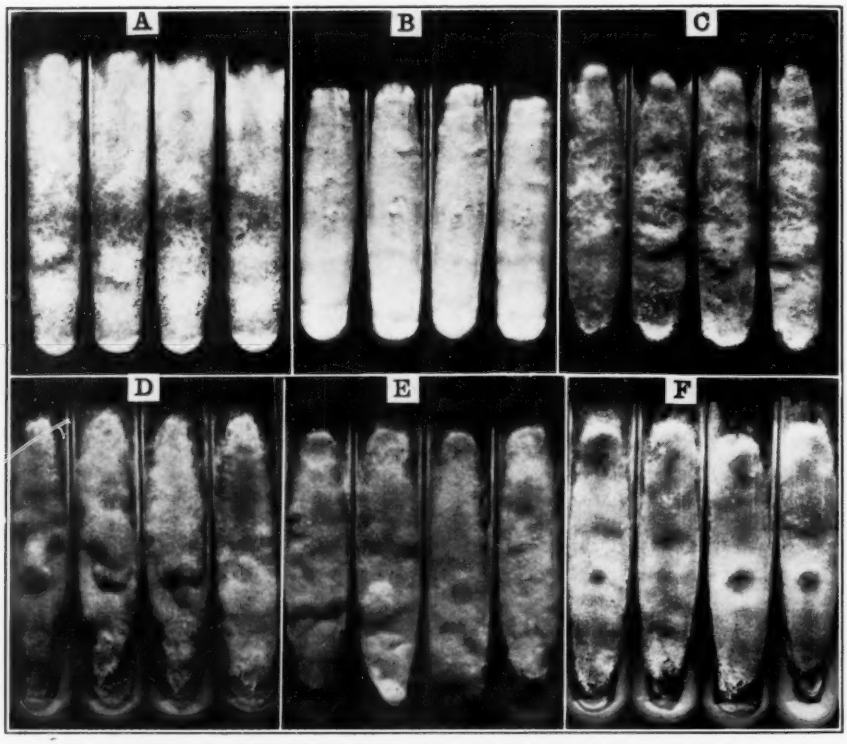

FIG. 4. A. Homotype *a* of *Botrytis cinerea*. B. Homotype *b*. C–F. Heterotypes *x*.

one of the *a* type tubes 25 single-spore cultures were grown, all of which were of the *a* type. Succeeding generations of *a* remained true to type (Fig. 2, A). From one of the *x*-type tubes in the F_1 25 monoconidial cultures separated into 7 of *x* and 18 of an entirely new type, *b* (Figs. 2, A and 4), with short, dense felt-like, yellow mycelium, quite unlike any other strain. The latter remained true to type through succeeding monospore generations (Fig. 2, A). In F_2, F_3, F_4, and F_5 the *x* types separated into *x* and *a* types, *x* and *b* types, or into *x*, *a* and *b* types (Fig. 2, A). The

net results so far, summarized in table 1 and figure 2, A, are the appearance of 2 homotypes, *a* and *b*, and several heterotypes *x*,[2] the heterotypes separating into heterotypes and homotypes and the homotypes remaining constant. This behavior strongly suggested that the *x* heterotypes were composed of various proportions of the 2 homotypes. According to this

TABLE 1.—*Synopsis of single-spore cultures from strain* x^1

Generations	Parents	No. of cultures	Progeny					
			x		*a*		*b*	
			No.	%	No.	%	No.	%
P_1	x^1	150	7	4.7	143	95.3		
F_1	*x*	25	7	28.0			18	72.0
	a	25			25	100.0		
F_2	*x*	25	18	72.0			7	28.0
	a	25			25	100.0		
	b	25					25	100.0
F_3	*x*	50	47	94.0	3	6.0		
	a	25			25	100.0		
	b	50					50	100.0
F_4	*x*	125	92	73.6	23	18.4	10	8.0
	a	75			75	100.0		
	b	50					50	100.0

suggestion, if the homotypes *a* and *b* could be combined into a heterocaryotic condition and their progeny analyzed by single-spore cultures, it should be found that their behavior would be similar to that of the progeny of x^1 with which we started. If such combination took place we should predict that 3 types would appear in the F_1, namely, the 2 parental types *a* and *b* and a number of intermediate or heterotypes. If *a* and *b* did not combine but merely grew together as a mixture we would expect the F_1 progeny to consist of the 2 parental types only. An attempt was made to combine *a* and *b* of the F_1 by taking a small amount of mycelium and spores from each and mixing them thoroughly together in warm agar; when the agar hardened, small amounts were transferred to 4 agar slants. When these cultures were 10 days old 25 single-spore cultures were made from each, giving 100 cultures from the cross. Of the 100 cultures, 50 were of the *a* type, 8 of the *b* type, and 42 of the *x* heterotype. Half of the cultures from each type were carried into the F_2. From each of these 50

[2] *x* designates a number of morphologically or culturally different types with only one thing in common, namely, their inconstancy.

tubes, 20 single-spore cultures were made with the following results (see Table 2 and Fig. 2, B). The 500 cultures from *a* all came true to type, as

TABLE 2.—*Synopsis of single-spore cultures from combination of strains a and b*

Generations	Parents	No. of cultures	Progeny					
			x		*a*		*b*	
			No.	%	No.	%	No.	%
P_1	*ab*	100	42	42.0	50	50.0	8	8.0
F_1	*x*	420	153	36.5	206	49.0	61	14.5
	a	500			500	100.0		
	b	80					80	100.0
F_2	*a*	20			20	100.0		
	b	60					60	100.0

did also the 80 cultures from *b*, but the 420 cultures from the *x* heterotypes separated into *a* and *b* homotypes and several *x* heterotypes. Homotype *b* was also successfully combined with *2* (see Fig. 3, A, second pair from left), a strain from a different geographic locality, with essentially the same behavior of the progeny as in the *ab* combination.

DISCUSSION

The results obtained in the F_1 and F_2 of the cross *ab* indicate that fusion of some sort has taken place and that the intermediates or heterotypes are composed of various proportions of *a* and *b*. The regularity and completeness with which the homotypes separated from the heterotypes indicate that the character-determining elements are discrete units of limited number. This leads to the suggestion that the basic unit of the individual is the *nucleus* and not the *cell*. In other words, a multinucleate spore is not an individual but a group of individuals, a colony, and it will not give rise to a genetically pure culture unless all its nuclei are genetically identical. The number of variants that may arise from a spore having 2 kinds of nuclei will depend on the number of nuclei it contains. For example, if the sum of the 2 kinds of nuclei in a given spore were 8, such a spore with independent nuclear assortment could give rise to 9 variants, *i.e.*, 2 homotypes and 7 heterotypes. Showing that genetically different nuclei can exist in the same cell would offer an explanation why monospore cultures so often give rise to variants, and we would then need only a mechanism for bringing together such diverse nuclei in the first place to account for variability in *fungi imperfecti* without attributing it in a vague sense to mutation. Such a mechanism has been shown to exist in the phenomenon

of anastomosis. We have shown that in *Botrytis cinerea* the hyphal cells and conidia are multinucleate and that anastomoses between neighboring hyphae are very abundant, forming connecting strands whose cellular contents are derived from those of different filaments. In the mixed growth of strains that compose *B. cinerea* in nature anastomosis between different strains could hardly fail to occur, resulting in a mixture of nuclei from 2 or more strains in the same cell and eventually in the same conidium. If our observation is valid, that nuclei of 1 strain migrate into cells of another strain by means of anastomosis, it will mean that the genetic composition of a given cell may be quite different from that of contiguous ones, depending upon whether or not it had anastomosed and, if so, how many of the different nuclei had passed into it. It would seem that to demonstrate such a condition one would have to analyze the genetic composition, not of cultures, but of single cells, and this, in effect, is what we have attempted to do in the experiments reported in this paper. In addition, we have made single-spore analyses of *Phoma terrestris*, *Verticillium alboatrum*, *Ramularia* sp., and *Fusarium* sp. with results comparable to those above, indicating that heterocaryosis may be common in *fungi imperfecti* in general, and perhaps equally common in the conidial stages of fungi with perfect stages.

SUMMARY

1. Single-spore isolations from 47 cultures of *Botrytis cinerea* collected in various parts of California showed the existence of a large number of more or less dissimilar morphological strains.

2. Single-spore isolations were repeated through a number of successive generations of several of these strains. Under such procedure some of the strains remained uniform, while others continued to break up into further variations.

3. One of these strains (x^1), which was subjected to single-spore culturing through 5 generations, gave rise to several types of cultures. Two homotypes (a and b) appeared that remained constant and several inconstant heterotypes (x) appeared that were intermediate. These latter, upon subsequent single-spore culturing, gave rise to other inconstant (x) forms and to the constant forms a and b.

4. Strains a and b were grown together in mixed cultures and their progeny analyzed by single-spore methods for 3 generations. In the F_1 and F_2 the parental forms a and b appeared and also a considerable number of inconstant types (x). The heterotypic strain x continued to produce heterotypes as well as the constant strains a and b.

5. The hyphal cells and conidia of *B. cinerea* are multinucleate, containing comparatively large numbers of nuclei.

6. Anastomosis of hyphae is very common in this species.

7. It is suggested that by the mechanism of anastomosis nuclei of 1 strain may migrate into the cells of other strains and thus give rise to cells and spores containing 2 or more kinds of genetically different nuclei.

8. It is suggested that the basic unit of the individual is the *nucleus* and not the *cell* and that a multinuclear spore is, therefore, not an individual but, in reality, a colony and it can, therefore, not give rise to a genetically pure culture unless all its nuclei are genetically identical.

9. From the above it is concluded that variable forms of *fungi imperfecti* may owe their instability, not to mutation, but to nuclear heterogeneity (heterocaryosis), that this condition can be brought about both *in vivo* and *in vitro* by nuclei of one strain entering the cells of another strain through anastomoses, and that the reassortment of these diverse nuclei is accomplished by the mechanism of anastomosis and unequal cell divisions.

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MOSAIC DISEASES OF TOBACCO: V. DECOMPOSITION OF THE SAFRANIN-VIRUS PRECIPITATE

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INTRODUCTION

A number of procedures have been found applicable to the purification of the virus of mosaic disease of tobacco. For instance, Vinson[1] reported precipitation of the virus by means of acetone, alcohol, ammonium sulphate, and safranin. Moreover, Vinson and Petre[2] have reported that they obtained a high degree of purification by precipitating the virus from juice of diseased tobacco plants with a solution of lead acetate, then removing the virus from the lead precipitate by elution with a neutral phosphate solution. This latter method effects a remarkable purification of the virus, but the procedure is time-consuming and laborious. Brewer, Kraybill, Samson, and Gardner[3] report the use of the ultracentrifuge and aluminum hydroxide in the purification of the virus.

Safranin in aqueous solution precipitates the virus from juice of diseased tobacco plants.[4] This precipitate may be centrifuged off, as it packs fairly well, thus permitting decantation of the supernatant liquid. Vinson and Petre[4] have described also a method of decomposing this precipitate and recovering the activity in the aqueous phase. The procedure is somewhat long and laborious, necessitating the subjection of the virus to a relatively high hydrogen-ion concentration.

Considerable care must be exercised in order not to inactivate the virus in the process. The original method of decomposing the safranin precipitate was not effective in eliminating the accompanying brown pigment, although there was a remarkable reduction in solids. The method of purification by precipitation with safranin was temporarily abandoned on account of the brown pigment that was not removed in the procedure.

Hope was never entirely abandoned, however, of eventually decomposing the safranin precipitate in such manner as to overcome the above-mentioned objectionable features. Such a method is here reported.

[1] Vinson, C. G. Precipitation of the virus of tobacco mosaic. Science n. s. **66**: 357–358. 1927.

[2] Vinson, C. G., and A. W. Petre. Mosaic disease of tobacco. II. Activity of the virus precipitated by lead acetate. Contrib. Boyce Thompson Inst. **3**: 131–145. 1931.

[3] Brewer, P. H., H. R. Kraybill, R. W. Samson, and M. W. Gardner. Purification and certain properties of the virus of typical tomato mosaic. Phytopath. **20**: 943–950. 1930.

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EXPERIMENTAL PROCEDURE

Early in the work on the virus problem it was learned that juice from diseased plants could be treated with Lloyd's alkaloidal reagent without reducing the infective power of the treated juice. Safranin, being a base, it was recognized that Lloyd's alkaloidal reagent might combine with it. Consequently, it was found that this reagent would remove safranin from aqueous solution. It was then discovered that the same reagent would remove safranin from an aqueous suspension of a safranin-virus precipitate, leaving an aqueous phase with infectivity equal to, and often greater than, that of the starting material.

Tops of diseased Turkish tobacco plants are frozen, then thawed and the juice is expressed with a hydraulic press. The expressed juice is centrifuged at about 3,000 r.p.m. for 15 minutes to free it of the larger suspended particles. If the juice is obtained from plants grown in the greenhouse, 5 cc. of a 1 per cent aqueous safranin solution will precipitate the virus from 25 cc. of juice. If the juice is from field plants, 10 or even 20 cc. of the 1 per cent aqueous safranin may be necessary to complete the precipitation. The safranin is added to the juice in a centrifuge tube, and, after mixing, the tube is allowed to stand for a few minutes, then centrifuged at 3,000 r.p.m. for about 10 minutes. The red precipitate packs sufficiently to allow complete decantation of the supernatant liquid. The precipitate is then washed, using a volume of redistilled water equal to the volume of the original juice sample.

The precipitate from 25 cc. of juice, after washing, is suspended in 25 cc. of redistilled water, and 1 gm. of Lloyd's alkaloidal reagent is added to the suspension. The sample is thoroughly mixed, then allowed to stand for about 30 minutes, mixing at intervals. At the end of this time the sample is centrifuged and the supernatant liquid decanted into a clean tube. If the safranin has not been completely removed, the treatment is repeated with sufficient Lloyd's reagent to remove every trace of the dye.

Starting with diseased Turkish tobacco plants from the greenhouse, the supernatant liquid thus obtained is free of safranin, usually opalescent and amber or nearly colorless. Some preparations, however, have been obtained that, so far as the eye could detect, were water-clear.

Table 1 shows the infective power of various samples of juice and also the infective power of the purified-virus preparation obtained from the respective juice samples by the method described. The data in this table show that the infective power of the purified-virus solution was uniformly equal to, or generally exceeded, that of the juice from which it was prepared.

More recent results indicate that the decomposition of the safranin-virus precipitate is best accomplished from 20 per cent acetone. In experiment

TABLE 1.—*Comparative infective power of the original juice and the purified virus preparation, obtained by precipitating the virus from the juice of diseased plants with safranin, then decomposing the precipitate with Lloyd's reagent*

Exp. no.	Juice from diseased plants diluted with an equal volume of distilled water			The purified virus preparation, from the corresponding juice diluted with an equal volume of water			Check plants	
	Inoculated		Diseased	Inoculated		Diseased	No. used	No. diseased
	No. of plants	No. of leaves	No. of plants	No. of plants	No. of leaves	No. of plants		
1	100	1	14	100	1	56	.....	.....
2	100	1	8	100	1	41	.....	.....
3	100	1	14	100	1	27	.....	.....
4	100	1	19	100	1	28	.....	.....
5	100	1	21	200	1	49	100	1
6	100	1	21	100	1	29	100	1
7	100	1	15	100	1	42	100	2
8	100	1	11	100	1	24	100	1
9	100	1	26	100	1	28	100	0
10	100	1	9	100	1	35	.....	.....
11	100	1	16	100	1	61	100	0
12	100	1	47	100	1	76	100	1

12 of table 1 the virus preparation was obtained by suspending the safranin-virus precipitate in 20 per cent acetone and decomposing with Lloyd's reagent. The dye seems to be more readily removed by Lloyd's reagent from 20 per cent acetone than from a purely aqueous suspension, and the infective power of the preparations containing 20 per cent acetone is fully as high as, if not higher than, the purely aqueous preparations. It is possible that the acetone decreases the basicity of the safranin and thus favors decomposition of the safranin-virus precipitate; or, it may decrease the basicity of Lloyd's reagent more than it does the safranin, thus making for a greater affinity for the safranin by Lloyd's reagent.

Use of Other Adsorbents. A number of other adsorbent earths have been tried for their pigment-removing power on juice from diseased tobacco plants and also on aqueous suspensions of the safranin-virus precipitate. Among the adsorbent earths, in addition to the Lloyd's reagent, that have been tried are: Fuller's earth, infusorial earth, kaolin, bentonite, and isarton. The German product, isarton, removes the safranin from an aqueous suspension of the safranin-virus precipitate more readily than does Lloyd's reagent, but at the reactions employed, isarton carried down the virus. Lloyd's reagent, however, removes the safranin from the safranin-virus precipitate in 20 per cent acetone more readily than does isarton. All

the other preparations were less effective in removing pigment from the juice and also from suspensions of the safranin-virus precipitate. Bentonite removed the virus from the juice of diseased plants at the reaction employed. Lloyd's alkaloidal reagent is outstanding in its property of removing pigment and leaving the virus in the supernatant liquid.

Effect of Suspended Material on Infectivity. Attention has already been directed to the fact that the purified virus preparations often show greater infective power than the juice from which they were prepared. Those purified preparations that show opalescence usually exhibit greater infectivity than preparations that appear clear to the eye.

Centrifuging at high speed for several minutes lowers the infective power of juice from diseased plants. It soon became evident that this lower infective power was probably not due to a greatly reduced virus content, since purified preparations from such juice were uniformly high in virus content, based on their infectivity.

These observations led to an investigation of the effect on infectivity of adding finely divided inert material to juice that had been centrifuged and also to purified virus preparations. When inert material was added to juice that had been centrifuged to form a fine suspension, the infectivity usually increased greatly.[5] The data in table 2 show that finely divided charcoal is very effective in bringing about this increase in infective power. In experiments 2 and 6, table 2, the infectivity of the juice was not increased by the addition of activated charcoal. This may have been partly due to the short time of contact with the charcoal at relatively low temperature before inoculating plants.

It has been suggested that the charcoal removes a substance that inhibits the action of the virus. That this is not the only factor involved is evidenced by the fact that freshly expressed juice from diseased tobacco plants may be much more infectious before than after it is centrifuged at high speed. The suspended material must also play some other part in this phenomenon.

Virus preparations may, therefore, be obtained so nearly free of suspended material that their infectivity is low, but on adding finely divided material to form a fine suspension the infectivity may be restored. This is well illustrated in the case of juice of diseased plants in experiment 4, table 2. In this experiment the centrifuged juice, on being inoculated into plants, caused 25 plants, out of 100 inoculated, to become diseased. After the addition of activated charcoal to this same juice sample, 65 out of 100 plants inoculated, became diseased.

A still better illustration of the effect of suspended material on infectivity is given by the data in experiments 12 and 13, table 3. In experi-

[5] Vinson and Petre, *loc. cit.*, 1931 (footnote 2).

TABLE 2.—*Influence on infective power of adding suspended material to a virus solution*

Experiment no.	No. of leaves inoculated per plant	Juice from diseased plants diluted with an equal volume of water		Virus solution prepared by decomposing the safranin precipitate (from the corresponding juice) with Lloyd's reagent. Diluted with an equal volume of water		Checks	
		No. of plants diseased out of 100 plants inoculated		No. of plants diseased out of 100 plants inoculated		No. of plants	
		Without activated charcoal	With activated charcoal	Without activated charcoal	With activated charcoal	Used	Diseased
1	1	21	43	25	43	100	1
				29	51		
2	1	15	16	45	63	100	2
				42	56		
3	1	11	30	23	43	100	1
				24	43		
4	1	25	65	....	....	100	1
5	1	26	63	....	....	100	0
6	1	9	8	35	51	....	....
7	1	16	35	61	81	100	0
8	1	47	80	76	95	100	1

ment 12 the virus preparation caused 1 plant out of 100 plants inoculated, to become diseased; but, after the addition of activated charcoal, 31 out of 100 plants inoculated, became diseased. In experiment 13, inoculation with the virus preparation caused none of the 100 plants inoculated to become diseased; but, after the addition of activated charcoal, 32 out of 100 inoculated plants became diseased.

From these experiments it is evident that the infectivity of a given virus preparation may not be a satisfactory indication of the virus content. It is now considered necessary to inoculate plants, not only with the preparation but also with the preparation after the addition of a given quantity of activated charcoal, before a dependable idea as to the virus content can be obtained. After inoculating with a particular sample, 100 mgm. of activated charcoal were added to each 10 cc. of the sample in order to assure an excess of suspended material. With an excess of suspended material, it would seem that the latter is eliminated as a limiting factor in infectivity.

In order that relative infective powers of virus preparations be reliable indexes of virus content, the preparations should be comparable in amount and type of suspended material present.

Application to Enzymes in General. It should be emphasized here that the above-mentioned conditions may influence the activity of all enzymes, and, if this be true, the present data on enzyme purification may be quite misleading. For instance, it is easy to see how, with the presence of sufficient suspended material of the proper type, a small quantity of enzyme would show as high activity as the original starting material. Hence, with lowered total solids but unimpaired activity, a high degree of purification may have been deduced. Our experience with the virus of mosaic disease of tobacco shows how such results could be obtained without any purification whatever being effected.

Effect of Safranin Concentration on the Precipitation of the Virus. In precipitating with safranin the virus from juice of diseased plants, an excess of the safranin solution is required. This is shown by the fact that when precipitation is incomplete the solution is still highly colored with the dye. By further addition of safranin the precipitation of the virus may be carried to completion, or approximately so.

Diseased tobacco plants grown in the field have a higher virus content than those grown under conditions of reduced sunlight, as in the greenhouse. Juice from diseased field plants requires a higher concentration of safranin to completely precipitate the virus than does juice from greenhouse plants. This suggests that there may be a definite or stoichiometric relationship between dye and virus in the safranin-virus precipitate. With juice from diseased Turkish tobacco plants grown in the greenhouse, 5 cc.

TABLE 3.—*Influence of safranin concentration on the precipitation of the virus from juice of diseased plants*

Exp. no.	No. of leaves inoculated per plant	No. of cc. of 1% aqueous safranin solution added per 25 cc. of juice	Solution obtained by decomposing the safranin-virus precipitate			Solution prepared by removing safranin from the supernatant liquid obtained on precipitating the virus with safranin			Checks	
			No. of plants inoculated	No. of plants diseased		No. of plants inoculated	No. of plants diseased		No. of plants	
				Without activated charcoal	With activated charcoal		Without activated charcoal	With activated charcoal	Used	Diseased
1[a]	4	5	10	9		10	6			
2[a]	4	10	10	10		10	5			
3[a]	4	15	10	10		10	3			
4[a]	4	20	10	8		10	0			
5[b]	4	5	10	7		10	6			
6[b]	4	10	10	7		10	0			
7[b]	4	15	10	10		10	0			
8[b]	4	20	10	9		10	0			
9[b]	1	5	100	42	56	100	24	31	100	2
10[b]	1	5	100	24	43	100	23	49	100	1
11[b]	1	10	100	35	51	100	3	13	.....	.....
12[b]	1	10	100	76	95	100	1	31	100	1
13[b]	1	10	100	76	95	100	0	32	100	1
14[b]	1	15	100	26	.....	100	7	4	100	0
15[b]	1	15	100	26	.....	100	3	.....	100	0
16[b]	1	15	100	28	.....	100	0	.....	100	0
17[a]	1	20	.....	.....	.....	100	1	2	100	0

[a] Juice from plants grown in the field.
[b] Juice from plants grown in greenhouse, then placed in the open for a few weeks.

of a 1 per cent aqueous solution will bring about approximately complete precipitation of the virus from 25 cc. of the juice. For juice from diseased plants grown in the field, 2, 3, or even 4 times this concentration of safranin may be necessary to complete the precipitation of virus from 25 cc. of the juice.

Table 3 shows the effect of safranin concentration on the precipitation of the virus from juice of diseased Turkish tobacco plants. In experiments 5 to 16, inclusive, of table 3, the juice was obtained from potted diseased plants that had been grown in the greenhouse, then placed in the open for a few weeks. In experiments 1, 2, 3, 4, and 17, the juice was obtained from diseased field-grown plants. The data show that, with the addition of 5 cc. of 1 per cent safranin solution to 25 cc. of the juice, considerable virus remained in the supernatant liquid. In fact, the supernatant liquid, after removal of safranin, was, in the case of experiment 10, as infectious as the solution obtained by decomposing the safranin precipitate. With the addition of 15 cc. or more of the 1 per cent aqueous safranin solution, the infectivity of the supernatant liquid was greatly reduced.

Effect of Treating the Juice with Lloyd's Reagent Previous to Precipitating the Virus with Safranin. Lloyd's reagent, when added to juice from diseased plants, removes pigment but, as already mentioned, does not reduce the infectivity of the treated juice when not more than 1 gm. is used to 25 cc. Table 4 shows the relative infective power of virus preparations from the safranin precipitate when, in one case, the juice was treated with Lloyd's reagent before precipitating with safranin and, in the other case, when it was not so treated. The data show that in most instances preliminary treatment of the juice with Lloyd's reagent, prior to precipitating the virus with safranin, did not lower the infective power of the preparation over that obtained from juice that received no treatment with Lloyd's reagent.

In experiment 3, table 4, the difference in infective power of the 2 preparations could easily have been due to a difference in physical condition—one was clear and the other opalescent.

Treatment of the juice with Lloyd's reagent previous to the addition of safranin did not reduce appreciably the total solid or organic solid content of the virus preparation obtained on decomposing the safranin precipitate. This is well illustrated by the data of table 5. The total ash shown for the solutions in table 5 is derived mainly from the Lloyd's reagent. This must be so since the safranin precipitate contains very little ash and also since extracting Lloyd's reagent with a corresponding amount of redistilled water gave about the same amount of ash in the extract as shown in the solutions of table 5.

TABLE 4.—*Effect of preliminary treatment of juice from diseased plants with Lloyd's reagent previous to precipitating the virus with safranin*

Experiment no.	No. of leaves inoculated per plant	Virus preparation obtained: juice first treated with Lloyd's reagent, then the virus precipitated with safranin and the safranin-virus precipitate decomposed with Lloyd's reagent		Virus preparation obtained by decomposing the safranin precipitate from the juice with Lloyd's reagent. Juice not previously treated with Lloyd's reagent		Checks	
		No. of plants diseased out of 100 plants inoculated		No. of plants diseased out of 100 plants inoculated		No. of plants	
		Without activated charcoal	With activated charcoal	Without activated charcoal	With activated charcoal	Used	Diseased
1	1	53	.....	56	.....	.....	.....
2	1	32	.....	41	.....	.....	.....
3	1	11[a]	.....	27[b]	.....	.....	.....
4	1	45	63	42	56	100	2
5	1	23	43	24	43	100	1
6	1	26	.....	28	.....	100	.....
7	1	21	.....	28	.....	100	.....

[a] This preparation was water clear.
[b] This preparation was opalescent.

TABLE 5.—*Effect of treating the juice with Lloyd's reagent, before adding safranin, on the solid and ash content of the virus preparation obtained by decomposing the safranin-virus precipitate with Lloyd's reagent*

Sample number	Virus preparation obtained by treating 25 cc. of juice from diseased plants with Lloyd's reagent. The virus was then precipitated with safranin and the safranin-virus precipitate decomposed with Lloyd's reagent		Virus preparation obtained by decomposing the safranin precipitate from 25 cc. of juice from diseased plants with Lloyd's reagent. Juice not previously treated with Lloyd's	
	Total solids in grams	Total ash in grams	Total solids in grams	Total ash in grams
1	0.0124	0.0074	0.0134	0.0087
2	0.0128	0.0084	0.0150	0.0085
3	0.0138	0.0084	0.0133	0.0081
4	0.0132	0.0085	0.0134	0.0081
5	0.0132	0.0083	0.0135	0.0090
6	0.0123	0.0081	0.0146	0.0089
Total in 500 cc.	0.2590	0.1630	0.2773	0.1710

Total solids in 500 cc. of the original juice—9.4260 gm.
" ash " " " " " " " " —5.9110 "

DISCUSSION

The need for a simple and rapid method of securing purified virus preparations has been felt for some time, especially a method that is not time consuming and that will effect appreciable purification of the virus, giving highly active preparations that may be demonstrated to contain a majority of the virus of the starting material. The safranin procedure herein described is believed to meet the need mentioned. It is quite possible that the procedure will prove applicable to the purification of any substance that will give a precipitate with safranin. This procedure, if applicable to other viruses, will make it possible for biologists, in general, to obtain stable purified virus preparations, as no special technique and care are necessary. The method is almost proof against mistakes. For those biologists who are interested in and are actively carrying on cultural experiments with virus, this method should have a particular appeal, for, through its application, most of the substances accompanying the virus are eliminated and a stable preparation is obtained. Sterile juice from diseased plants is unstable, it clouds readily, and precipitates form on standing. The purified material is, therefore, much superior to the unpurified juice for purposes of inoculating media.

SUMMARY

Lloyd's alkaloidal reagent removes the safranin from an aqueous suspension of the safranin-virus precipitate, leaving the virus in the supernatant liquid.

The purified virus solutions thus obtained were fully as infectious as the juice of diseased plants from which they were prepared.

At the reactions employed, Lloyd's reagent has proved more satisfactory for decomposing the safranin-virus precipitate than kaolin, infusorial earth, Fuller's earth, bentonite, or isarton.

The addition of finely divided inert material to form a fine suspension often increases the infectivity of a virus preparation.

In order that relative infective powers of virus preparations be reliable indexes of virus content, the preparations should be comparable in amount and type of suspended material present.

The greater the virus concentration of a juice sample, the greater the amount of safranin required to bring about complete precipitation of the virus.

Previous treatment of the juice with Lloyd's reagent does not appreciably reduce the total solids in the preparation obtained by decomposing the safranin precipitate.

Total solids in the solution obtained by decomposing the safranin-virus precipitate with Lloyd's reagent represent about 3 to 4 per cent of the total solids of the original juice. About half of this 3 to 4 per cent, however, is ash that is derived mainly from the Lloyd's reagent.

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PHYTOPATHOLOGICAL NOTES

Preliminary Note on a Phytophthora Root Disease of Chestnut.—A phycomycetous fungus that appears to be the same as *Phytophthora* (*Blepharospora*) *cambivora* (Petri) Buis., the cause of the ink disease of European chestnuts, has been isolated from the blackened roots of dying American chestnuts from Georgia, South Carolina, and Tennessee. The types of hyphae and sporangia and the dimensions of these, as well as most of the cultural characteristics, are similar to those ascribed to *P. cambivora*. To complete the identification, further studies are being made of the morphology and cultural reactions. Thus far the oospore stage, which is found in the cortex of infected seedlings in Europe, has not been found in our plants. Like European investigators of *P. cambivora*, we have had difficulty in isolating from naturally infected chestnuts this Phytophthora, which appeared in only 3 per cent of the total number of cultures, but it was easily isolated from young plants from known infested areas. Reisolations from dead inoculated plants were readily made.

Four months after inoculations in the greenhouse with the American Phytophthora, there had died 72 per cent of 82 seedlings of the native *Castanea dentata* (Marsh.) Borkh., 74 per cent of 43 seedlings and 17 per cent of 54 larger plants of the European *C. sativa* Mill., 67 per cent of 32 seedlings of southern chinquapins, 3 per cent of 63 seedlings and 5 per cent of 57 larger plants of the Japanese *C. crenata* Sieb. and Zucc., and none of 14 seedlings and 2 per cent of 56 larger plants of the Chinese *C. mollissima* Blume. These percentages are not strictly comparable, because all the inoculations were not made simultaneously, because some of the inoculations were made in wounds and others in soil and because the plants varied in age and were from 1 to 4½ feet high. Some of the plants are still dying. The native *C. pumila* (L.) Mill. is also susceptible to the organism, but, so far, neither the Chinese *C. henryi* Rehd. and Wils. nor the Chinese *C. seguinii* Dode has become infected. Two of 81 inoculated seedlings of *Quercus prinus* L. have also become infected. In an experimental planting of young chestnut plants in infested soil in Georgia, 3 plants out of 6 of *C. sativa* died in the first season and 39 plants of *C. mollissima* and 25 of *C. crenata* appeared healthy. In the examinations of many thousands of plants in the experimental forest plantings of *C. crenata* and *C. mollissima* in all of the Southern States no case of the root disease has been noted. The high susceptibility of the American and European chestnuts and the comparative resistance of Asiatic chestnuts to the American Phytophthora agree with the results of European investigators of *P. cambivora*.

The facts that a few weeks' search in the South was sufficient to establish the presence of the American Phytophthora in 3 States, that the dying of native growth from blight (*Endothia parasitica* (Murr.) P. J. and H. W. Anderson) makes the recognition of trees dying from other causes difficult in many places, and that it is difficult to culture the fungus from naturally infected roots indicate that the disease is widespread in the South and suggest the possibility that the fungus may have been present in this country for many years. Dying and recession of the chestnut at the lower altitudes at various places from Maryland to Mississippi have been occurring for about 100 years. These have been attributed to the Armillaria root rot, to forest fires, and to other causes, without an exhaustive study having been made. It is strongly suspected that this Phytophthora root disease has played an important, if not the primary, part in this recession. If subsequent study verifies the identity of the American Phytophthora and *Phytophthora cambivora* of Europe, the reason for the minor differences observed may be that these strains may have grown for many generations on different hosts and on two continents. The comparative resistance of the four species of Asiatic chestnut and the marked susceptibility of American and European species make one suspect that the original home of this fungus, as of the chestnut blight, is Asia.

The symptoms of this disease varied considerably on the trees examined. Some large trees wilted suddenly and others gradually died from the top downward over a period of 2 years or more. Frequently a surface root remained alive for some time after the other roots were killed. Taproots of most of the trees were more severely affected than lateral ones, and from many of the larger roots an ink-like slime oozed from the affected areas and discolored the attached soil. In some cases the roots were blackened where they joined the crown but were normal in their outer parts. In other cases isolated cankers occurred on the roots.

Pathologists and others interested are requested to report cases where the presence of this disease is suspected.—MARGARET MILBURN and G. F. GRAVATT, Division of Forest Pathology, Bureau of Plant Industry, United States Department of Agriculture, Washington, D. C.

The Odor of Bunt Spores.—In a recent paper[1] an account was given of the isolation of trimethylamine from spores of *Tilletia levis* Kühn collected at Winnipeg, Canada, in 1931. This substance was considered to be responsible for the odor usually associated with bunt spores. Spores of *T. tritici* (Bjerk.) Wint., also grown at Winnipeg, in 1931, did not possess this odor and trimethylamine could not be isolated from them.

[1] Hanna, W. F., H. B. Vickery, and G. W. Pucher. The isolation of trimethylamine from spores of *Tilletia levis*, the stinking smut of wheat. Jour. Biol. Chem. **97**: 351–358. 1932.

In the discussion of these results the writers made the following statement: "It has been shown by several workers that *Tilletia tritici* comprises several physiologic forms which differ from one another in their parasitic capabilities. The possibility exists that certain of these forms may be able to produce trimethylamine, whereas others may not. The spores of *Tilletia tritici* used in this investigation were considered to belong to a single physiologic form. However, if the hypothesis just suggested is correct, other forms of this fungus may occur, the spores of which contain trimethylamine."

The writer of this note has since had opportunity to examine spores of *Tilletia tritici* at the Station Centrale de Pathologie Végétale, Versailles, France. These spores gave off a faint odor of trimethylamine. Spores of several physiologic forms of *T. tritici* kindly supplied by Dr. E. F. Gaines, of the State College of Washington, Pullman, Washington, have also been examined and they, too, smelled distinctly of trimethylamine. In view of these observations it is evident that trimethylamine may be present in the spores of some strains of *T. tritici* and absent from those of others.

Using pure cultures made from single secondary conidia, which are apparently haploid, crosses have been made between *Tilletia levis* and the strain of *T. tritici* lacking trimethylamine. The first-generation hybrid spores resulting from this cross resemble in appearance those of the *T. levis* parent, as has already been reported by Flor,[2] and emit an odor of trimethylamine. In this cross, therefore, the factors for smooth spore wall and odor are dominant.—W. F. HANNA, *Dominion Rust Research Laboratory, Winnipeg, Canada.*

New Developments in treating Pecan Rosette with Chemicals. Experiments conducted in the latter part of the growing season of 1931 indicated that pecan rosette could be prevented by treating the leaves with an 0.8 to 1.0 per cent solution of ferric chloride or ferric sulphate, as reported in a recent issue of PHYTOPATHOLOGY.[1]

With the enlargement of these experiments undertaken at the beginning of the 1932 season, more or less conflicting results began to appear. The experiments included injection of iron salts into dormant trees; application of iron salts to the soil around the trees, while they were still dormant; after the foliage was well developed, spraying by various procedures with both ferric and ferrous sulphate; and dipping terminal branches that showed the rosette symptoms in solutions of iron salts. The only favorable results were

[2] Flor, H. H. Heterothallism and hybridization in *Tilletia tritici* and *T. levis*. Jour. Agr. Res. 44: 49–58. 1932.

[1] ALBEN, A. O., J. R. COLE, and R. D. LEWIS. Chemical treatment of pecan rosette. Phytopath. 22: 595–601. 1932.

associated with the small-scale experiments where galvanized iron containers were used in handling the solutions. It was further found that the iron salts used contained appreciable quantities of zinc. Accordingly, a small series of experiments were undertaken, using shellacked crocks instead of galvanized buckets. The effects of zinc sulphate and zinc chloride solutions were compared with the effect resulting from iron sulphate solution. One immersion in the iron solution failed visibly to improve conditions, while zinc sulphate and zinc chloride solutions restored the new leaves back to normal condition. These results were secured with trees located on both alkaline and acid soils.

Roberts and Pierce[2] reported beneficial effects on peach foliage following zinc-lime sprays used for controlling bacteriosis, and, accordingly, in our further experiments, zinc sulphate and zinc-lime sprays were included. Trees sprayed with zinc lime 2–2–50 were greatly improved but not so much as were those trees sprayed with zinc sulphate. The most satisfactory results were obtained by using an 0.18 per cent zinc sulphate ($ZnSO_4 \cdot 7H_2O$) and 0.012 per cent zinc chloride ($ZnCl_2$) solutions. Burning of the foliage resulted when stronger solutions were used. The chlorine radical is apparently more toxic than the sulphate radical; at least 7.1 times more zinc was applied without burning with the sulphate form than with the chloride.

These experiments were practically completed before our attention was directed to the experiments of Chandler, Hoagland, and Hibbard,[3] reporting on little leaf or rosette in fruit trees and noting iron sulphate treatments of apple, pear, peach, plum, cherry, and walnut, as well as grape. They found that iron applications to the soil gave generally favorable but frequently erratic results and report that zinc, rather than the iron, itself, is the corrective factor. While not definitely excluding the possibility of zinc as an essential element for the fruit trees, their conclusions emphasize the probable changes in soil constitution and soil flora, and experiments with injections of zinc solutions and spraying are suggested as desirable for clarification of the problem. They report that, although the iron solutions when free of zinc impurities appeared without effect, larger quantities of pure zinc salts are required to secure the favorable responses of the trees than when mixed solutions of iron and zinc are employed, which, apparently, explains our favorable results with iron solutions containing quantities of zinc somewhat lower than those reported above as the optimum for the zinc solutions.

[2] ROBERTS, JOHN W., and LESLIE PIERCE. Zinc-lime: a fungicide for the peach. Phytopath. **22**: 415–427. 1932.

[3] CHANDLER, WM. H., D. R. HOAGLAND, and P. L. HIBBARD. Little-leaf or rosette, in fruit trees. Proc. Amer. Soc. Hort. Sci. **28** (1931): 556–560. 1932.

Our experiments in spraying foliage with zinc sulphate or zinc-lime sprays and also the experiments in dipping terminal parts of branches showing pronounced rosette symptoms in zinc solutions and the prompt and favorable response of the trees to such treatments apparently indicate that zinc is an essential element for the healthy development of the pecan tree.—A. O. ALBEN, Bureau of Chemistry and Soils; J. R. COLE, Bureau of Plant Industry; and R. D. LEWIS, Bureau of Chemistry and Soils, U. S. Department of Agriculture, Shreveport, Louisiana.

REPORT OF THE FIFTH ANNUAL COTTON-ROOT-ROT CONFERENCE[1]

The fifth annual conference of workers with the cotton-root-rot disease caused by *Phymatotrichum omnivorum* (Shear) Duggar was held at the University of Texas, Austin, Texas, on February 1 and 2, 1932. The meeting was attended by 33 plant pathologists, agronomists, soils specialists, chemists, botanists, and horticulturists connected with the work, and approximately 50 visitors.

Director A. B. Conner of the Texas Agricultural Experiment Station and Dr. J. J. Skinner, Bureau of Chemistry and Soils, U. S. Department of Agriculture, presided over the various sessions. Following an address by Director Conner on the purpose of the conference, the 55 technical reports of experimental work were presented during the first day; these are summarized below in their order on the program. On the second day, general summaries of the progress of the work were presented in 3 addresses, one by Dr. J. J. Taubenhaus of the Texas Agricultural Experiment Station; another by Dr. D. C. Neal of the Bureau of Plant Industry, U. S. Department of Agriculture; and another by Mr. Paul R. Dawson, of the Bureau of Chemistry and Soils, U. S. Department of Agriculture.

STUDIES ON LIFE HISTORY

Physiologic Specialization of *Phymatotrichum omnivorum*

Morphological behavior of different isolations. During 1931, 2 additional strains of the fungus, after 14 to 18 months' growth on artificial media, lost their capacity to produce strand hyphae or sclerotia. In several isolations of the fungus, specialized fusion of the large-cell hyphae has been observed, the appearance being similar to that of conjugation of certain filamentous algae. (D. C. Neal and K. C. Gunn, Bureau of Plant Industry, U. S. Department of Agriculture).

Inoculation experiment with physiologic forms. Nine different isolations, of which some belonged to each of 5 physiologic forms (cultural) of the fungus, caused typical root rot of inoculated cotton plants, irrespective of the sources from which the cultures had originally been isolated (cotton, beets, carrots, and alfalfa) and irrespective also of the length of time the cultures had been grown on artificial media (3 months for the youngest to over 3 years for the oldest strain). Three strains that had grown the more slowly in artificial culture also caused the slower development of root rot. (W. N. Ezekiel and J. J. Taubenhaus, Texas Agricultural Experiment Station).

[1] Prepared for the conference by the following committee: W. N. Ezekiel, Chairman, D. C. Neal, Paul R. Dawson, and E. B. Reynolds.

GROWTH AND NUTRITION OF THE FUNGUS

Nutritional studies on growth in artificial culture. The growth rate of the fungus was not affected by the relative concentration of dextrose in culture solutions until the supply was almost exhausted. Preliminary tests gave no evidence of production of staling products during the period of active growth. Carrot juice added to synthetic media resulted in marked increase in growth; an accessory growth-promoting substance may be involved, but certain results suggest that the effect may be due merely to the additional sources of nitrogen. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge, Texas Agricultural Experiment Station).

Growth in synthetic media. Ammonium nitrate and ammonium sulphate, each used in Duggar's solution at rates to supply about 12.4 gm. of nitrogen per liter, inhibited growth of the fungus; while calcium nitrate, sodium nitrate, and potassium nitrate at the same rates yielded abundant growth, the best being with the calcium nitrate. The filtrates of these cultures became less acid as growth of the fungus progressed. (D. C. Neal, R. E. Wester, and K. C. Gunn, Bureau of Plant Industry, U. S. Department of Agriculture).

Effects of anaerobic conditions on growth. Growth was inhibited by anaerobic conditions and notably restricted by carbon dioxide concentrations above 25 per cent. The fungus did not grow with 100 per cent of nitrogen or carbon dioxide, but after such exposure for 8 days was still able to grow when returned to aerobic conditions. Aerobic requirements for growth of the fungus may explain effects on root rot following subsoiling. Such treatment may activate the sclerotia, thereby lessening the chances of survival of the fungus through the winter. (D. C. Neal and R. E. Wester).

Greenhouse studies of Phymatotrichum omnivorum. Attempts to inhibit growth of the fungus or control infection by competition of other soil organisms met with failure. Cultures of 2 species of Fusarium, 2 of Aspergillus, 1 Mucor, and 1 Penicillium introduced into soil cultures did not prevent root-rot infection of cotton plants following inoculation from cultures of *P. omnivorum.* (D. C. Neal and L. G. McLean, Bureau of Plant Industry, U. S. Department of Agriculture).

Preliminary irradiation studies. Six-day and 2-week old cultures, respectively, were irradiated for 2 to 30 minutes under a mercury-vapor lamp, with the view of inducing sporulation. With the longer irradiation, definitely injurious results were noted, but no sporulation was observed. (J. J. Taubenhaus and W. N. Ezekiel).

SCLEROTIAL STAGE OF THE FUNGUS

Distribution of sclerotia in infested areas. In an alfalfa field in Arizona sclerotia were most abundant at 6 to 24 in. deep, with a few at a depth of

54 in. Near a dead Chinese elm tree, 8,203 sclerotia were obtained, most abundantly at 6 to 42 in., but a few at a depth of 84 to 90 in. Sclerotia were distributed unevenly in the soil, occurring in pockets. (C. J. King, Bureau of Plant Industry, U. S. Department of Agriculture).

Occurrence of sclerotia with regard to soil types and hosts. A post-hole digger was used to sample soil to depths of 2 ft. for sclerotia, which were recovered by washing soil through sieves with running water. Sclerotia were found in 13 counties in Texas, in soil of 14 different types, near 27 different affected hosts. (J. J. Taubenhaus and W. N. Ezekiel).

Occurrence of sclerotia in nature. In excavations in Wilson soil at the Greenville Station, sclerotia were found near old tree roots and in primary centers of infection in fields where cotton followed several years of clean fallow or nonsusceptible crops rather than in continuous cotton plots. They were found usually in groups, at depths of 4 to 18 in., but mostly at 4 to 12 in., and near small cotton rootlets rather than along the taproots of the plants. (H. C. McNamara and D. R. Hooton, Bureau of Plant Industry, U. S. Department of Agriculture).

Observations on the formation of sclerotia in culture. Growth of the fungus in films of media, inverted over special paraffin-beeswax cells, was followed microscopically. The hyphae anastomosed and entangled to form pseudosclerotia. These differed microchemically and morphologically from sclerotia, as produced in soil or cultures, particularly by the absence of the cuticularized outer wall of the sclerotia. (Elizabeth Moore, University of Texas).

Factors affecting sclerotia production. Formation of sclerotia in synthetic media of many formulas correlated closely with nutritive conditions suitable for rapid and abundant vegetative growth of the fungus and was inhibited by any changes detrimental to growth, suggesting that field treatment militating against free growth of the fungus might have a further desirable effect in discouraging production of sclerotia. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge).

Laboratory studies on the longevity of sclerotia. Sclerotia secured in the summer of 1929 from a carrot field at Temple were stored in small vials filled with moist Houston clay-loam soil. After more than 2 years, germination tests showed many of these sclerotia still viable and capable of vigorous growth. (J. J. Taubenhaus and W. N. Ezekiel).

SPORE STAGES OF THE FUNGUS

Inoculations with Phymatotrichum spores. Cotton plants grown in containers at College Station were inoculated periodically with Phymatotrichum spores, of which some were placed near the uninjured taproots, others introduced through epidermal or cambial injuries, and others in-

jected into the cambium of the root. No infection occurred, although high percentages of infection were secured with check plants inoculated with fresh cotton-root inoculum. (J. J. Taubenhaus and W. N. Ezekiel).

HOST PLANTS

New hosts, symptoms. New additions to the root-rot host list from the Temple substation included 18 species of weeds and 27 species and varieties of ornamentals. (S. E. Wolff, Texas Agricultural Experiment Station).

Inoculation experiments with cacti. Ornamental cacti of a number of genera and species succumbed to artificial inoculation with root rot, while noninoculated plants remained normal. (J. J. Taubenhaus and W. N. Ezekiel).

Further inoculation experiments with monocotyledons. No infection was secured at College Station in continued inoculations during 1931 on monocotyledonous plants, including corn, sorghum, and various liliaceous plants; although high percentages of infection occurred on the interplanted cotton and carrot plants used as inoculated checks. Monocotyledonous plants are apparently immune from Phymatotrichum root rot. (J. J. Taubenhaus and W. N. Ezekiel).

INFECTION AND RESISTANCE

Histologic studies on the process of infection. Cotton seedlings, grown aseptically in tubes of agar, and inoculated with sclerotia from a pure culture of *Phymatotrichum omnivorum,* were fixed at intervals. After 5 days, the fungus was present in the first outer layer of epidermal cells; after 8 days it had penetrated the parenchyma; and after 12 days, had entered the vascular system and pith of affected rootlets. Invasion was both inter- and intracellular. (J. J. Taubenhaus and W. N. Ezekiel).

Reaction of cotton seedlings grown in the presence of pure cultures of Phymatotrichum omnivorum. Pea, bean, and cotton seedlings grown in soil cultures of the fungus in the laboratory failed to become infected, although sclerotial masses in the cultures were penetrated by the roots of the plants. (L. G. McLean).

Growth of the fungus in plant juices as correlated with resistance of plants to root rot. Phymatotrichum omnivorum grew profusely in undiluted, expressed juices from dicotyledonous plants, susceptible to root rot, but was generally inhibited in undiluted juices from roots of monocots, which are immune. Good growth occurred, however, in diluted juices from the monocots, indicating that immunity is due probably to specific toxic materials in monocots. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge).

HIBERNATION AND TRANSMISSION OF ROOT ROT

Rôle of winter and spring vegetation at Temple. A study of natural infection of 3 winter annuals at Temple, Texas, showed no infection until about April 20. With *Sitilias multicaulis,* 9 per cent of the plants were infected by April 27 and 58 per cent by June 1, when only 13 per cent of *Hamosa nuttalliana* plants were infected and none of *Vicia leavenworthii.* Under the same conditions, 25 per cent of the perennial *Ipomoea trifida* plants were infected by February 9, and 53 per cent by May 15. (S. E. Wolff).

Rôle of winter and spring vegetation in south Texas. In fields in Bexar and Dewitt Counties, grown continuously in cotton, in corn following cotton, and in fallow following cotton, respectively, 14 species of winter and spring weeds assisted in hibernation of Phymatotrichum. In February, 1930 and 1931, 1 to 5 per cent of these weeds showed root rot, and by May, infection ranged from 1 to 15 per cent. (J. J. Taubenhaus and W. N. Ezekiel).

Nursery plants as possible carriers. Balled and nonballed nursery plants from a root-rot-infested area were transplanted into root-rot-free soil at College Station. Some of the nursery plants, as well as interplanted cotton plants, succumbed to typical Phymatotrichum root rot, presumably transmitted on infected roots of the nursery plants or as sclerotia in the balled soil. Check plants remained free of root rot. (J. J. Taubenhaus and W. N. Ezekiel).

OCCURRENCE OF ROOT ROT AND ESTIMATION OF LOSSES

Possible occurrence in other countries. A puzzling cotton disease in India had been considered possibly Phymatotrichum root rot. Microscopic examination of infected cotton roots from India and cultures from the roots indicated that the disease is distinct from Phymatotrichum root rot. The symptoms resembled alkali injury as commonly found in El Paso County. *Sclerotium bataticola* was usually present. (J. J. Taubenhaus and W. N. Ezekiel).

The root-rot fungus indigenous to Arizona deserts. Conidial mats of the fungus were found along a roadway, in a desert area 12 miles from the nearest cultivation. Mycelium of the fungus was found on the roots of 6 native plant species, and sclerotia were found in the soil. (C. J. King).

Root rot in river bottoms. Typical Phymatotrichum root rot has recently been found in flooded river bottoms, along the Trinity River and in a few places along the Brazos River, on roots of cotton plants and of native pecan stumps that were still alive and sprouting in spite of continued cultivation. (J. J. Taubenhaus and W. N. Ezekiel).

Occurrence of root rot in certain alluvial soils. Although root rot did not occur in the major portions of the alluvial soil areas in Bell and Milam Counties, Texas, in 1931, the disease was prevalent in certain individual fields on Catalpa, Ochlockonee, and Trinity clay soils. (H. E. Rea, Texas Agricultural Experiment Station).

Root rot in relation to soil types and moisture. At the Temple substation, root-rot infection for 4 years averaged 39.5 per cent on a Houston clay area, in which the percentage of soil moisture averaged 19.68 per cent in the first 3 ft.; while infection was 56.2 per cent on a deep phase of Houston black clay in which moisture percentage averaged 29.47 per cent. Wilting point on the Houston clay is about 12 per cent and on the Houston black clay about 19 per cent. (Henry Dunlavy, Texas Agricultural Experiment Station).

Root-rot losses in Texas. Estimates for root-rot losses on cotton, as prepared by the Division of Crop and Livestock Estimates, were discussed. For the few years for which data were available, there was an apparent high correlation between root-rot and boll-weevil damage. (F. H. Whitaker, Bureau of Agricultural Economics, U. S. Department of Agriculture).

Estimation of cotton-crop losses. Yields of cotton in a root-rot area were corrected for seasonal weather influences by comparison with yields in a near-by bottomland field where root rot did not occur. For the 6-year period, the estimated percentage of the crop lost from root rot in one continuous cotton plot averaged about 69 per cent of the percentage of plants killed by the disease and for another plot, about 50 per cent. It is suggested that percentage reductions in yield may be estimated roughly as averaging about 50 per cent of the percentages of plants killed by root rot prior to the first picking. (W. N. Ezekiel and J. J. Taubenhaus).

Date of wilting as related to losses. In some experimental plots at College Station, cotton plants killed by root rot 2 months or more before first picking bore practically no crop; plants killed a little more than a month before harvest averaged less than a boll and only 0.79 gm. of lint per plant; plants succumbing 3 weeks before harvest averaged more than 2 bolls and 3.21 gm. of lint per plant—as compared to 2.3 bolls and 4.6 gm. of lint average for normal plants. (W. N. Ezekiel and J. J. Taubenhaus).

CONTROL STUDIES

SOIL CONDITIONS, INCLUDING SOIL REACTION

Root-rot occurrence in relation to chemical characteristics of soils. While root-rot infestation is, in general, heaviest on soils of calcareous nature and alkaline reaction and is lightest on noncalcareous soils of neutral or slightly acid reaction, data do not indicate a definite correlation with the content of calcium carbonate or the pH, particularly within a

given soil type of Texas blackland soils. On the other hand, there appears to be, as a rule, a significantly higher content of organic carbon and total nitrogen, as well as a higher carbon-nitrogen ratio, in soils from noninfested areas. Similarly, examination of soils from localized root-rot spots reveals a marked trend toward a lower content of reactive or available organic matter than is the case with soils from root-rot-free areas of the same fields. In a Wilson clay-loam field, where the carry-over and initial appearance of root rot each season are largely confined to limited areas of shallow-phase soil, the less infested deep-phase soil is distinguished by a lower calcium carbonate content, a lower pH, a higher available moisture and nitrate content throughout the crop season, and by a higher organic carbon content, total nitrogen, carbon-nitrogen ratio, and available phosphoric acid. In the blackland soils studied, the chemical differences most consistently correlated with relative or complete freedom from root rot are those indicative of a lower degree of erosion damage and a higher state of fertility. (E. R. Collins, W. V. Black, D. R. Ergle, and P. R. Dawson, Bureau of Chemistry and Soils, U. S. Department of Agriculture).

Studies on basis of the soil-reaction correlation with root rot. In originally acid soils, in which various salts were incorporated, growth of the fungus in soil chambers was not increased with additional available supplies of calcium, sulphate, phosphate, nitrate, and probably potassium ions beyond that expected from the relative changes in pH. The favorable effect of alkaline soils is probably not the specific effect of any of these ions. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge).

A field-plot test of sulphur for the gradual control of root rot. Applications in 1929, to plots of noncalcareous Lufkin soil at College Station, of sulphur at low rates based on laboratory tests, resulted in progressive decrease of root rot in the 3 treated plots; while the disease has become more prevalent in 3 lime-treated plots and varied individually in the 6 check plots. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge).

FERTILIZER APPLICATIONS

A 12-year manurial experiment on root-rot control. Application of organic manures in deep furrows beneath cotton rows was effective in reducing infestation in an experiment at Sacaton, Arizona, conducted for 12 years. Corral manure, at 12 tons per acre for 8 years, reduced root rot from 72 per cent to 1.1 per cent; there was a general decrease of infestation also in the control plots, but not to the same extent. (C. J. King, Claude Hope, and E. D. Eaton, Bureau of Plant Industry, U. S. Department of Agriculture).

Effects of fertilizer in relation to root-rot control. In the 1931 experiments in the blackland region of Texas by the Bureau of Chemistry and

Soils, as in previous years, properly proportioned ratios of nitrogen and phosphoric acid accelerated maturity and increased yields to such a degree as to be effective in completely offsetting root-rot losses. On cotton following sorghum, nitrogen fertilizers offset the depressing effect of the latter, which is one of the most valuable rotation crops for root-rot-infested ground. Experiments repeated during 3 to 4 years on the same plots showed that the benefits of fertilizers are cumulative, due to residual effects. Fertilizers most effective in accelerating plant growth and increasing cotton production caused actual reduction in the proportion of plants dying from the disease. This direct effect of fertilizers on root rot assumes significance only where the severity of infestation has first been reduced by rotation or tillage treatment or after several successive years of fertilizer application. (H. V. Jordan, J. H. Hunter, and P. R. Dawson, Bureau of Chemistry and Soils, U. S. Department of Agriculture).

Response of cotton to commercial fertilizers under root-rot conditions. In cooperative experiments in Bell County, use of 4–8–4, 4–8–0, and 4–0–0 fertilizers at 400 lbs. per acre increased yields 132, 145, and 48 lbs. of seed cotton per acre, respectively, in 15 tests on Houston black clay; 83, 84, and 35 lbs. in 9 tests on Houston clay; and 111, 99, and 51 lbs. in 9 tests on San Saba clay. (H. E. Rea).

Concentration of soluble salts as affecting growth of the fungus in soils. In soil-chamber tests with 3 soil types, growth of the fungus was prevented with around 5 per cent concentration in the soil solution of soluble salts, such as potassium nitrate, ammonium nitrate, sodium chloride, and potassium phosphate. Insoluble materials, such as calcium carbonate and calcium phosphate, apparently had no toxic effects, even at higher concentrations. (W. N. Ezekiel, J. J. Taubenhaus, and J. F. Fudge).

SOIL DISINFECTANTS

Treatment of cotton root rot with ammonia. In cultures, both mycelia and sclerotia were killed by dilute ammonium hydroxide and by short exposures to the gas. Forty hours after applying 6 per cent ammonium hydroxide solutions around large cotton plants in the field, the plants were removed and placed in moist chambers. No mycelial growth developed on the treated roots. (D. C. Neal).

Treatment of primary centers of infection with formalin. Applications of various chemicals at Greenville for 3 seasons to primary centers of infection suggest the feasibility of such control for small areas. In 1931, 2 per cent and 4 per cent formaldehyde solutions were applied in Wilson clay soil and penetrated 12 to 18 in. within 24 hours. A majority of the centers treated early in the season showed no further advance of the disease, although late-season treatments were not so effective. (H. C. McNamara).

Field-plot tests with some soil disinfectants. Disinfectants have been incorporated yearly since 1929 in field plots, at College Station, planted to cotton. During 1931, good control was obtained in plots treated with some of the chlorophenol-mercury and nitrophenol-mercury compounds, while root rot caused almost total loss in the check plots. (J. J. Taubenhaus and W. N. Ezekiel).

Laboratory tests of initial and residual efficiency of disinfectants. In soil-chamber tests, 3 organic-mercury compounds of the ethyl-mercury type showed as high initial efficiency as chlorophenol-mercury and nitrophenol-mercury compounds of much higher mercury contents. After contact with the soil for a month, however, the fungicidal value of the ethyl-mercury products had decreased, while that of the other materials was approximately unchanged. Phenyl mercury acetate proved relatively inefficient. (W. N. Ezekiel and J. J. Taubenhaus).

Sodium chloride, gasoline, and some other disinfectants. Under field conditions, at College Station, sodium chloride at the rate of 3,000 lb. per acre failed to control root rot, which is in agreement with results of laboratory tests, which suggest that concentrations required would approximate 20,000 lb. of sodium chloride per acre. (J. J. Taubenhaus and W. N. Ezekiel).

BARRIERS TO LIMIT SPREAD OF ROOT ROT

Sulphur barriers and graminaceous crop barriers. Barriers of soil containing 2 or 4 per cent of sulphur and barrier rows of sorghum were again tested both in boxes and under field conditions at College Station. In no case did root rot spread from the inoculated cotton plants on one side of the various barriers to the noninoculated plants on the other side. (J. J. Taubenhaus and W. N. Ezekiel).

Root-rot barriers in the field. Root rot has not crossed earth barriers containing crude carbolic acid, waste motor oil, or open trench barriers 2 ft. deep, in tests for 4 years at Greenville. In 1931, no spread was observed through barriers of manure, lignite, sulphur, calcium chlorate, and waste oil, while spread was observed beyond salt, marcasite, and sand barriers. (H. C. McNamara and D. R. Hooton).

SUBSOILING

Effects of subsoiling on occurrence and spread. Portions of 6 heavily infested fields on Houston soils were thoroughly subsoiled during the summer and early fall of 1930. In 1931, the numbers of cotton plants killed by root rot in the subsoiled areas were reduced in all cases (to 5 to 9 per cent) until after the crop was practically mature, while on the nonsubsoiled areas the losses remained very heavy (40 to 70 per cent). This effect was associated with a lower rate of spread of root rot from early centers of

infection on the subsoiled plots. Increases in yield from reduction in root rot and increased productivity as a result of subsoiling ranged from nearly 300 lb. to over 800 lb. of seed cotton per acre. The tillage was equally effective, whether it followed a rotation crop of sorghum or a highly infected cotton crop. During the early growing season the subsoiled plots showed a significantly higher total soil-moisture content and a distinct trend toward a higher available moisture, higher nitrate, and higher available organic-nitrogen content. There is evidence that factors such as these, favoring plant growth and productivity on subsoiled ground, play a rôle in the suppression or delay in spread of root rot. (P. R. Dawson, H. V. Jordan, and E. R. Collins).

Effects of deep tillage on root rot. In November, 1930, 15 plots at the Temple substation were subsoiled to a depth of 15 to 18 in. In 1931, 11 of the subsoiled plots had less root-rot infection at the end of the season than adjoining check plots, and 12 made a higher yield. Subsoiled plots averaged 32 per cent root rot and yielded 735 lb. of seed cotton per acre, while adjoining checks averaged 46 per cent root rot and yielded 573 lb. of seed cotton. (H. Dunlavy).

ROTATION

Root rot in rotation. An acre of cotton at the Temple substation, which showed over 99 per cent root-rot infection in 1927, was planted to nonsusceptible crops for the next 3 years, replanted to cotton in 1931, and the root-rot infection was 13.7 per cent at the end of the season. An adjoining acre, also with 99 per cent infection in 1927, was planted continuously to cotton and developed 41 per cent infection in 1931. (H. Dunlavy).

Root rot in various rotation and cultural treatments. In experiments at the San Antonio Field Station for 23 years, root-rot losses have been less with cotton grown in rotation with nonsusceptible crops, such as corn, sorghums, or small grains, than with cotton grown continuously on the same land. Three-year rotations are little, if any, less effective than 4-year rotations but are appreciably more effective than 2-year rotations. Persistent carry-over in plots in rotations was definitely associated with survival of the fungus on dead roots of native trees. (Geo. T. Ratliffe, Bureau of Plant Industry, U. S. Department of Agriculture).

Results of a 42-month fallow. Viable sclerotia were found to a depth of 17 in. under wilting cotton plants, planted at Temple in plots following 42 months of clean fallow. Large numbers of nonviable sclerotia were found 21 and 28 in. deep. (S. E. Wolff).

The effect of rotation on root rot. In rotations at Weslaco, initiated in 1927, plots planted to sorghum or corn in 1930 showed no root rot in the cotton at harvesting time in 1931. Other plots in which susceptible crops

had been grown in 1930 showed 68 to 100 per cent root rot. Yields of cotton following sorghum or corn were more than twice those obtained with cotton following cotton. (W. J. Bach, Texas Agricultural Experiment Station).

RESISTANT SPECIES, VARIETIES, AND STRAINS

Grape varieties. At Weslaco, varieties of grapes previously reported promising as resistant rootstocks again showed resistance in further tests, which included artificial inoculation of the plants. (W. J. Bach and J. J. Taubenhaus).

Nursery and ornamental plants. The hackberry, live oak, and yaupon develop complete resistance as the plants become older. The coralberry was found to be resistant to root rot in tests at College Station. (J. J. Taubenhaus and W. N. Ezekiel).

Nursery plants. Species of the mulberry and willow families were found very susceptible, while of 472 individuals in 11 species of the peach family tested at Temple only 2 plants died. Members of the honeysuckle family showed high resistance. (S. E. Wolff).

Alfalfa varieties and other legumes. Of a large number of alfalfa varieties and other legumes that were tested at Iowa Park substation for possible resistance none has yet shown any promise of even partial resistance to root rot. (J. J. Taubenhaus and L. E. Brooks).

REPORT OF THE SIXTEENTH ANNUAL MEETING OF THE PACIFIC DIVISION OF THE AMERICAN PHYTOPATHOLOGICAL SOCIETY

The meetings of the Pacific Division of The American Phytopathological Society were held in conjunction with those of the Pacific Division of the American Association for the Advancement of Science and Affiliated Societies at Pullman, Washington, June 16–17, 1932.

There was an average attendance of 28 members at the 3 half-day sessions of the society. Nineteen papers were read, abstracts of which follow the present report.

At the business meeting the following officers were elected to serve the society the next 2 years:

President	H. E. Morris, Montana State College, Bozeman, Montana.
Vice President	F. P. McWhorter, Oregon State College, Corvallis, Oregon.
Secretary-Treasurer	B. A. Rudolph, University of California Deciduous Fruit Station, San Jose, California.
Councilor	J. M. Raeder, University of Idaho, Moscow, Idaho.

Aside from the commendable harmony throughout our own meetings, the meetings of the entire Pacific Division, A. A. A. S., and Affiliated Societies were characterized this year by a delightful informality that contributed greatly to sustaining interest throughout the sessions. Dinners at which members of various biological societies met and fraternized were the order rather than social gatherings restricted by professional preferences. Such dinners, attended by people engaged in widely unrelated research, were the occasion of much merrymaking and pleasant foolery, especially the one given on the College Commons; the presidents of various societies were obliged to discuss, impromptu, some topic assigned them. Ours explained "What the Phytopathologists Have Contributed to the Depression," to the great amusement and satisfaction of all.

B. A. Rudolph, *Secretary-Treasurer*

ABSTRACTS

Perennial canker and anthracnose fungi: host relations and cultural differences.— J. R. Kienholz. *Gloeosporium perennans* was observed naturally infecting quince trees and fruits, and the service berry (*Amalanchier pallida*) during 1931, while *Neofabraea malicorticis* was found on the native Oregon crab apple, *Malus rivularis*.

Plants successfully inoculated with both the perennial canker and anthracnose fungi include the yeach, service berry, wild cherry, plum, apricot, Oregon crab apple, flowering quince, cherry, hawthorn, mountain ash, and rose haws. Either the service berry or Oregon crab apple may have formed a native host plant for these organisms.

Dyes of the tri-phenyl-methane series inhibited spore germination at high dilutions. When malachite green was incorporated into either potato-dextrose or Coons' synthetic agar at a concentration of 1–200,000, the growth of 3 strains of *Neofabraea malicorticis* was inhibited from 20–90 per cent more than the growth of the 5 strains of *Gloeosporium perennans* used. Fairly accurate measurements gave surprisingly constant results, which give this method merit as a means of rapidly distinguishing these fungi by laboratory means. For constant results mycelial transfers from cultures previously transferred at least twice on a standard laboratory medium should be used, since spore material or very new cultures exhibit a higher degree of sensitiveness to the toxic action of the dyes.

The spotting of pineapple leaves caused by Pseudococcus brevipes (Ckl.), the pineapple mealybug.—W. CARTER. Under field conditions in Hawaii two general types of spotting of pineapple leaves result from feeding by *Pseudococcus brevipes*. One appears as the typical chlorotic area following Coccid feeding. The other is designated as green spotting. This latter type is caused by the feeding of certain individuals and is not common to the species. Colonies have been maintained for a period of 1 year without any green spots resulting. Other colonies have consistently produced green spots. Another colony was apparently inherently capable of producing green spots, for these appeared at rare intervals.

Attempts at transmission of green spots, either by mechanical means or by transfer of nongreen-spotting mealybugs to healthy leaves after feeding on green spotted tissue, were all unsuccessful. Evidence that the ability to produce green spots is transmitted from the mature mealybug to her young is conclusive.

The green-spotting mealybug is frequently distinguishable from those unable to produce green spots by a difference in body color, a dark brown color of the body fluids that imparts a grayish cast to the waxy covering of the insect. The hereditary nature of the ability to produce green spots lead to a consideration of the possible relationship between the intracellular symbionts of the insect and its secretions.

The pineapple mealybug (Pseudococcus brevipes (Ckl.)) and wilt of pineapples.—W. CARTER. Mealybug wilt is common to all the pineapple-growing areas in Hawaii and is the major known source of collapse of pineapple plants in the islands. The disease assumes many forms, dependent upon the size and time of onset of the initial mealybug population, the age, vigor, and succulence of the plant, and the fact that recovery in various degrees is commonly encountered. The relationship between the pineapple mealybug and wilt of pineapples has been conclusively demonstrated.

Quick wilt develops after a sudden attack by a fairly large colony of mealybugs, which may, however, feed for only a short time. Slow wilt is the result of a continuous attack by a gradually increasing population of mealybugs; its incidence is governed by the size of the mealybug colony and the length of time the colony feeds on the plant.

The disease is believed to be due to the secretion by the insect of a nonliving but toxic principle that is variably diffusible, sometimes affecting only the area of leaf actually fed upon by the insects, sometimes producing wilt in 2 or 3 contiguous leaves, or, as is usually encountered under field conditions, a wilted condition of the entire plant.

Comparison of quick and slow wilts suggests an antitoxic reaction by the plant,

which enables it to accommodate itself to large but, gradually developed, populations of the mealybug. The toxicity of *Pseudococcus brevipes* appears to vary with the kind and condition of the insect's host plant.

Observations on the ascospore discharge of pear-scab fungus, Venturia pyrina.—L. CHILDS. Scab is one of the most important diseases affecting pears in parts of northwestern Oregon and western Washington. Since pear varieties grown in these areas exhibit great differences in their reaction to fungicides, general recommendations cannot be made for controlling scab. Lime-sulphur and Bordeaux sprays cannot be used with safety on tender-skin fruits, while various sulphur sprays including dry-mix, atomic sulphur, calcium mono-sulphide, and others have given indifferent results.

While recording ascospore discharge for *Venturia pyrina*, perithecia were noted in scabbed twig lesions. Although very similar to those of the scab organism, these perithecia were more superficial and apparently bore no setae. This associated organism is provisionally identified as *Mycosphaerella tulasnei*, having a Cladosporium imperfect form. Previous ascospore-discharge records for the scab parasite have been complicated by this second organism and hence dates of earliest spore expulsion may be inaccurate. However, both organisms discharge their spores from overwintered leaves during rain periods only, for at least as late as July. During 1932 the first Mycosphaerella spores were discharged on March 26. The rôle of this associated organism is unknown, having been previously reported only on cereal crops. Wherever it occurs on fallen leaves, scab perithecia are extremely rare or absent, even though scab lesions are present.

The fungicidal control of Phytophthora heart rot of pineapple plants.—F. P. MEHRLICH. Heart rot of the pineapple plant in Hawaii is caused by 4 described species of Phytophthora. Experiments in naturally infested areas involving 2 of these fungi have shown that Bordeaux 1–0.65–3 as a dip is an effective and economical preventive. This formula was selected from 67 formulae of 22 liquid fungicides and 12 dry fungicides tried. Bordeaux 1–0.65–3, applied by completely immersing planting material in it, has given better control than larger quantities of the same or different fungicides applied in other ways. A single application in 8 separate experiments has given the following control under conditions extremely favorable to development of the disease. Average control 79.23 per cent, range 63.40–91.59 per cent; disease in adjacent non-treated plots, average 48.8 per cent, range 22.70–84.99 per cent. The total concentration of Bordeaux 1–0.65–3 may be doubled or either constituent varied 50 per cent without injuring plants treated. The cost for materials is $7.00 per acre of 10,000 plants. Specific recommendations for the use of this treatment have been made.

Indications of differential susceptibilities of various classes of planting materials have been presented.

Some experiments with mechanical transmission of the curly-top virus.—B. F. DANA. The need for a mechanical method of transferring the curly-top virus, naturally transmitted by the beet-leaf hopper, *Eutettix tenellus* Baker, has induced the writer to investigate this problem. Of the methods tried, a modification of the technique used by Sein in transmitting sugar-cane mosaic (Jour. Dept. Agr. Puerto Rico **14**: 49–68. 1930) has been used most extensively. By this method, attempts have been made to transfer the disease from sugar beet to sugar beet, tomato, and spinach, and from tomato to sugar beet.

The first attempt to transfer the virus from sugar beet to sugar beet was successful in 8 out of 16 plants in 1 lot. A recently infected inoculum plant was used. Subsequent

trials have given low percentages of successful transfer. The percentage of successful transfer from sugar beet to tomato and spinach and from tomato to sugar beet has also been low.

It is apparent that this virus is most active soon after it is introduced into a plant and at this time is more amenable to mechanical transfer from plant to plant than at any subsequent time. The variability of the results obtained with this multiple-needle method indicates modifying factors that must be determined before the method can be used in routine work. This method has given 100 per cent transfer when used with a mosaic of cruciferous plants, which illustrates the variable in facility with which the different viruses may be transmitted by mechanical methods.

Narcissus-mosaic symptoms.—F. P. MCWHORTER. Narcissus-mosaic symptoms show great varietal variation and considerable variation among individuals of the same variety. Plant responses resulting from reduction in vigor occur in all varieties. The reduction in vigor leads to early maturity and renders infected plants especially susceptible to Stagonospora leaf spot and Ramularia blight. Symptoms accountable to chlorophyll repression include yellow striping, mottling, marbling and, occasionally, yellowing of entire leaves. These chlorophyll disturbances can be analyzed by photographing the leaves between thick, greenish glass plates, using daylight, an A "red" filter and panchromatic plates. The leaf surfaces of some varieties become roughened, apparently, as a result of the disease. The leaves of some varieties curl; those of others bend in the plane of the leaf. Shortly after blooming, necrotic areas may develop in epidermal tissues of the shoot and exhibit a bronzing effect. The perianth lobes of some varieties show hyaline streaks. The disease is bulb-perpetuated and the symptoms of each individual remain reasonably constant from year to year.

A preliminary analysis of tulip breaking.—F. P. MCWHORTER. The theory is advanced that the usual variegated flower-color condition of tulips, commonly called "breaking" and technically referred to as "mosaic," results from the action or interaction of two viruses. One of these viruses carries a color-adding factor and produces no visible effect on leaves; the other removes flower color and strongly stripes the leaves.

It was observed that certain varieties, when broken, tend to segregate into plants or parts of plants (clumps) bearing strongly darkened flowers or decidedly bleached flowers. By encouraging this segregation through selection and by using inocula prepared from the parts of flowers where the color was removed and darkened, respectively, it has been possible to secure the viruses in almost pure condition. The color-adding virus has little effect on plant growth and may be of practical use in producing "new" varieties. The color-removing virus is extremely virulent and reduces plant growth to $\frac{1}{3}$ normal. Cross inoculations with the juice from leaves of mosaic-diseased *speciosum* lily indicate that these contain a virus indistinguishable from, if not identical with, the color-removing virus of tulips. The relationship of the color-adding virus to other plant viruses has not been determined.

A new method of inoculating with viruses.—L. K. JONES. A method of inoculating plants with viruses has been developed that has proved very effective in transmitting the latent and veinbanding viruses of potato as well as the virus of tobacco mosaic. With this method the worker can inoculate a larger population in a given time with a minimum of preparation of equipment. The possibility of contamination is almost eliminated.

Round swab sticks or "applicators," as used by the medical profession, are broken in half. Absorbent cotton is firmly rolled onto one end of each half applicator and securely fastened with thread. These swabs are placed in a cannister with the cotton ends down and sterilized in the autoclave at 20 pounds' pressure for 1 hour. Six-inch pot labels are placed in a cannister with the pointed ends up and sterilized.

In making inoculations from growing plants, portions of the plant tissue are broken off with the sterilized swab and pot label. The plant tissue is macerated on the label, then rubbed over the foliage to be inoculated with the swab. The pot label acts as a support of the leaf while being inoculated. By using care, neither the tissue used as inoculum nor the plant to be inoculated comes in contact with any source of contamination.

Dried host tissue may be used in this method by macerating the tissue in a small amount of water in a sterilized Petri dish with the aid of the sterilized swab and label.

The sources of the viruses that cause streak of tomato.—L. K. JONES. Streak of tomatoes as found in the greenhouses of the State of Washington is caused by a combination of the latent potato virus and the common tobacco-mosaic virus. Once the disease appears on plants in the greenhouse it is spread very rapidly by pruning and cultural practices.

The tobacco-mosaic virus appears to be introduced in the greenhouses, mainly, by the use of tobacco by the workmen, although it may sometimes be transmitted to tomatoes from petunias, *Solanum nigrum*, or other host plants found in the greenhouse.

It has been shown that the potato-latent virus can be brought into the greenhouse and transmitted to tomatoes in two ways. First, from volunteer potato plants in the tomato-plant bed, which is due to the use of soil that has previously grown potatoes. Forced contact of the potato and tomato foliage will transmit the latent virus. Second, workmen handling potatoes, in sorting or removing sprouts, can transmit the latent virus if tomato plants are handled, following work with the potato tubers.

Aspergillus sclerotiorum, n. sp., and its relation to decay of apples.—G. A. HUBER. A new species of Aspergillus is described as belonging to the *Aspergillus ochraceus* group, *sulphureus* series. This organism, for which the name *A. sclerotiorum* is suggested, was found to be pathogenic on apples, causing decay both at ordinary and at cold-storage temperatures. When inoculated into sound, ripe Jonathan apples, it produced lesions 42–46 mm. in diameter in 42 days at 22°–25° C. It produced lesions 28–38 mm. in diameter in 90 days at 6°–8° C. and lesions 10–14 mm. in diameter in 120 days at 0°–2° C.

The influence of moisture on the development of the Cercosporella foot rot of winter cereals.—RODERICK SPRAGUE. *Cercosporella herpotrichoides* Fron., the cause of a destructive foot rot of winter cereals in the Columbia Basin of Washington and Oregon, occurs in semiarid prairie regions where the annual rainfall ranges from 14 to 24 inches. Its optimum development occurs in those parts having just under 20 inches a year.

A warm, moist March, followed by an equally moist, cool April and early May, brings on severe infection, especially when the plants have been forced by prolonged growth the preceding autumn.

Foot rot thrives in fine sandy-loam soil during the time of year when this soil has abundant moisture. When the dry season begins, usually in early summer, the surface-soil moisture is quickly reduced to almost oven-dry condition and foot rot almost ceases to develop. All experimental evidence and field observations show that soil moisture,

which is directly correlated with seasonal precipitation, is the determining factor in the relative severity of the disease in different years.

(Cooperative investigations between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture, and the Oregon and Washington agricultural experiment stations.)

The importance of lenticel infection of apples by Penicillium expansum.—K. F. BAKER and F. D. HEALD. Blue mold (*Penicillium expansum*) of apples is generally considered as essentially a wound parasite, although infection through the lenticels has been reported. Stricter grading and improvements in packing equipment since 1925 would indicate a decrease in the amount of injured fruit in packed boxes. This is not consistent with the fact that the annual loss from blue mold has remained fairly constant in those years.

Examination of apples in commercial storage in Yakima and Wenatchee, Washington, has shown that infection by blue mold through the lenticels frequently occurs. The maximum amount of such infection found in any lot was 33.3 per cent; incidence up to 10 per cent is fairly common. Two or 3 such infections per apple are not unusual, and up to 14 have been observed. Lenticel infection has been observed in 8 apple varieties. Splitting of the skin of the decayed areas and the emergence of the fungus have made difficult the determination of the infection court.

Lenticel infection may be responsible for a considerable portion of the average annual loss from blue mold decay, and it, rather than mechanical injury, is the cause of many of the lots showing high percentages of blue mold in storage.

Walnut blight and its control in Oregon.—P. W. MILLER. Studies on walnut blight and its control carried on in Oregon during the past 2 years show (1) that the causal organism, *Ps. juglandis*, overwinters in this State primarily in infected buds; (2) that meteoric water is the most important agency concerned in the spread of primary and secondary infections; and (3) that the use of home-made Bordeaux mixture is an effective means of controlling walnut blight where a suitable schedule of applications is used during the critical period for infection. In tests carried on in 1930 and 1931, respectively, Bordeaux mixture 3–3–50 seemed to be practically as effective as greater strengths. At least two applications of Bordeaux appeared to be necessary to control blight satisfactorily in grafted orchards. Best results from spraying were obtained when the applications were made (1) just before blooming of the pistillate flowers and (2) just after blooming, when the stigmas of the pistils were turning brown. Under severe epidemic conditions a third treatment applied about 2 weeks after the second application appeared to be necessary to control blight. Dusting has not given sufficiently good control thus far to recommend its use. Injury to set of nuts occurred from spraying with Bordeaux when the pistillate flowers were fully open to receive pollen. Bordeaux injury of young foliage was observed but it did not appear to be extensive enough to appreciably damage the trees or affect the crop unfavorably. Altering the method of preparing Bordeaux did not eliminate this foliage injury. Spraying with Bordeaux appears to have resulted in a profit to the grower through increased yield and quality of nuts. Indirect benefits through reduced hold-over infections are indicated.

Mosaic disease of horse-radish.—B. F. DANA and F. P. MCWHORTER. Horse-radish plantings in Washington County, Oregon, deteriorated during the 1930–1931 season. At digging time most of the plantings were dwarfed and yellowed. Roots averaged small

and were unsightly because of rough scaly surfaces and unsalable because of pithy texture and frequent dark streaks.

Root cuttings from plants showing various stages of decline were potted and forced at different temperatures. The foliage was more or less stunted and leaf blades were strikingly segmented in a fern-like manner. The young leaves exhibited a prominent mosaic-like mottle, characterized by interveinal pale green areas interspersed with dark green. Clearing of veins was not noticeable. Old leaves developed black elongated lesions in the epidermis and outer cortex of the petioles.

Cross inoculations to turnip and mustard were made with the Oregon material by means of a modification of the Sein multiple-needle method (Jour. Dept. Agr. Puerto Rico **14**: 49–68. 1930). One hundred per cent of the plants inoculated developed a mosaic similar to that on the horse-radish. Symptoms were apparent within 10 to 12 days, plants became dwarfed, and many died within a short time.

This preliminary work indicates that a serious mosaic is partly responsible for the reported deterioration of horse-radish.

The sources of contamination of the normal apple and spore load.—G. A. HUBER and F. D. HEALD. The first contamination of normal apples occurs in the orchard. Analyses of the air in various orchards at harvest time showed from 25 to approximately 500 spores of fungi per cubic foot. Apples carefully picked from the trees and so handled as to prevent further contamination showed from 14,000 to 159,100 spores per apple. Apples from surface-irrigated plots showed an average of 36,766 spores per apple, while those from overhead-irrigated plots showed an average of 119,616 spores.

"Dirty" picking boxes, important sources of contamination of normal apples, showed an average load of 108,050,160 spores of fungi on the interior surface. A box with the maximum contamination carried a load of 109,958,400 spores on the inner surface of the bottom boards only, of which 32,987,520 were Penicillium types, the majority being *P. expansum*.

The air in packing houses during the packing season showed from 32 to 994 spores per cubic foot, fewer spores occurring in houses where sanitary measures were practiced. Various processes used for the removal of the arsenical residue from apples did not reduce the spore load of normal apples to any extent in 1926. In 1927, the improved methods reduced the spore load to a certain extent but not enough to have an appreciable effect in the prevention of storage rots. In 1930, the methods used, namely, acid, Laux, and Brogdit-Brogdex, greatly reduced the spore load of the apples, but neither acid nor alkali processes had noticeable effect on the types of fungi present. Gloves worn by sorters showed from 12,100 to 40,000 spores per square inch in the palms.

Physiology and pathogenicity of species of Phytophthora that cause heart rot of pineapple plants.—F. P. MEHRLICH. Heart rot of the pineapple plant in Hawaii is caused by *Phytophthora cinnamomi* Rands, *Ph. meadii* McRae, *Ph. melongenae* Sawada, and *Ph. parasitica* Dastur. An extended geographic range of the disease is given. Newly found hosts of these fungi include common weeds and green-manure plants, which may aid their survival in the absence of pineapple plants. Three of these fungi may also rot green pineapple fruits. Symptoms and causal organisms relate pineapple heart rot to coconut bud rot.

Detailed evidence is presented that *Pseudopythium phytophthoron* Sideris is a synonym of *Phytophthora cinnamomi* Rands. It occurs in virgin soil associated with *Dicranopteris emarginata* (Brack) Robinson. Cultures isolated locally have been compared

with authentic cultures of Rand's isolations and found similar to them in host range, temperature relationships, physiology of conidial production, morphology of mycelium, and reproductive structures. This organism may rot green fruit and cause root rot in addition to heart rot.

A method for isolating these fungi from soil is described. It consists in incubating susceptible leaf tissue in a mixture of infested soil and sterile water. Pure cultures are isolated from the tissue by planting or by inoculating pineapple crowns and subsequently planting them. The method has been used for a variety of purposes.

Enzymes with Cladosporium.—H. CAMPBELL.

The longevity of the latent and veinbanding viruses of potato in dried leaf tissue.—B. BURNETT.

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Bethel, Ellsworth	1911	1925
Burger, Owen F.	1911	1928
Delafield, Maturin L. (patron)	1915	1930
Earle, F. S.	1911	1929
Fitch, H. W.	1922	1926
Howard, N. O.	1916	1930
Jaczewski, A. (patron)	1921	1932
Kauffman, Calvin H.	1911	1931
Lyman, George R.	1914	1926
Midumoto, Tunakiti	1926	1927
Morse, W. J. (charter)	1908	1931
Nishida, Toji	1919	1927
O'Donnell, F. G.	1920	1928
Orton, W. A. (charter)	1908	1930
Pammel, L. H. (charter)	1908	1931
Patterson, Flora W. (charter)	1908	1928
Pennington, L. H.	1911	1929
Pritchard, F. J.	1924	1931
Rekowski, Charles W. de	1924	1929
Smith, Erwin F. (charter)	1908	1927
Thaxter, Roland	1911	1932
Thomas, Ralph C.	1921	1928
Umetu, Sanpatiro	1927	1929
Walton, R. C.	1914	1926
Wright, W. H.	1928	1929

[3] Members who have died since the publication of the list in PHYTOPATHOLOGY in October, 1925.